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ASCII Encoding of Biomedical Signals for SMS Transmission

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***Abstract* – We present in this work, a technique which consists in coding the values of physiological signals using the ASCII (American Standard Code for Information Interchange) code and transmit the texts obtained through SMS (Short Message Service) protols. The SMS texts received by a mobile phone are decoded to restore the physiological signals. Previously, the SMS messaging protocol was useful in telemedicine only to set appointments between patients and doctors, to alert patients when to take medications and to specify the doses of the drugs. Using our technique, biomedical signals of any kind such as ECG, EEG, changes in temperature or blood sugar levels can be transmitted through SMS. In the set of ASCII code, there are several invisible characters and many other characters that are interpreted by the operating systems as instructions. These classes of characters are a priori, serious handicaps for our applications but we developed strategies to overcome such difficulties. Our technique is in the news coming for telemedicine as it enables the transmission of biosignals at very low costs. We have obtained very satisfactory results.**

***Keywords* – Biomedical Signals, ASCII Code, SMS, Telemedicine.**

I. Introduction

Telemedicine is the aspect of medicine that uses telecommunications to transmit medical information (images, reports, records, etc.), in order to obtain remote diagnostics, expert advice, ongoing monitoring of a patient or a therapeutic decision. Telemedicine includes several different applications and the common point is the evaluation of the patient, or patient data, by one or more medical professionals, without direct physical interaction. The diffusion of mobile technologies as well as advancements in their innovative application to address health priorities has evolved into a new field of electronic health (eHealth) known as mobile health (mHealth) [1]. Mobile technology is helping with chronic disease management, empowering the elderly and reminding people to take medication at the proper time [2]. The mobile health can be an alternative that would make a significant contribution to public health problems in developing countries. Indeed, the penetration of mobile phone networks in many low- and middle-income countries surpasses other infrastructure such as paved roads and electricity. It is projected that by the end of 2016, there will be 10 billions mobile devices in use around the world. The diffusion of cell phones into the remotest parts of these countries makes phone-based telemedicine a key option for curative interventions as well as preventive measures. Electronic Health (eHealth) is the future of healthcare and mobile eHealth (mHealth) is the future of eHealth [2]-[4]. Remote monitoring devices enable patients to record their own health measures and send them electronically to physicians or specialists. Many works have been devoted in recent years on mobile telephony applications for recording and transmitting Electrocardiogram 'ECG) [5] - [9]. Mobile telephony system includes many applications such as short message sender (SMS) and multimedia message sender (MMS). SMS provides message sending only in text format while MMS communication applications provide message sending services in text, photo, graphic, animation, slide presentation, voice or video clip formats. In [10], an architecture and algorithm of MMS frame work for a mobile telemedicine system is proposed: MMS establishes a proper communication between the doctor who is working in the hospital and the nurse who is providing assistance to the patients at patient's living place. SMS have also been intensively used to manage chronic diseases. In [11], insulin measurement, insulin intake and other data of the patient are sent to physician through SMS for continuous health monitoring. SMS are also sent to patient to remind them on some activities. A review on Diabetes Management systems via Mobile Phones is given in [12]. Some other applications of SMS for improving healthcare management are found in [13]–[15].

In low incomes countries, the vast majority of the population lives in rural areas and cannot access medical doctors as these specialists of healthcare are rare and mostly being in few big cities. There is also a lack of hospital facilities because of the very limited financial resources. We propose a system that can bring a partial solution to these situations by allowing the poor patients everywhere in those countries to be able to record and send their physiological parameters to physicians at distant, through SMS mobile telephony protocols. Our system is new. The SMS are not used for alerts or reminding purpose as it has been the case up to now. Rather the text messages do map physiological signals such as ECG, EEG, and more. Samples values of biomedical signals are then encoded using ASCII code into text format before transmission through SMS.

The main components of a remote medical diagnosis system shown in figure 1 include bio signal sensors, processing units, data communication networks, and medical service centers. The patient vital physiological signals can be measured, stored and processed through type of sensors, type of data communication and monitoring device. Signal processing and medical algorithms can also be performed for automatic diagnosis. Our aim in this work is firstly to collect vital physiological signals from patients and code these signals into text format. The text obtained is processed and transmitted as an SMS to a distant doctor. At the doctor terminal,

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decoding schemes are applied and the physiological parameters values are visualized or plotted as curve in natural format. In this way, we transmitted many biomedical signals successfully.

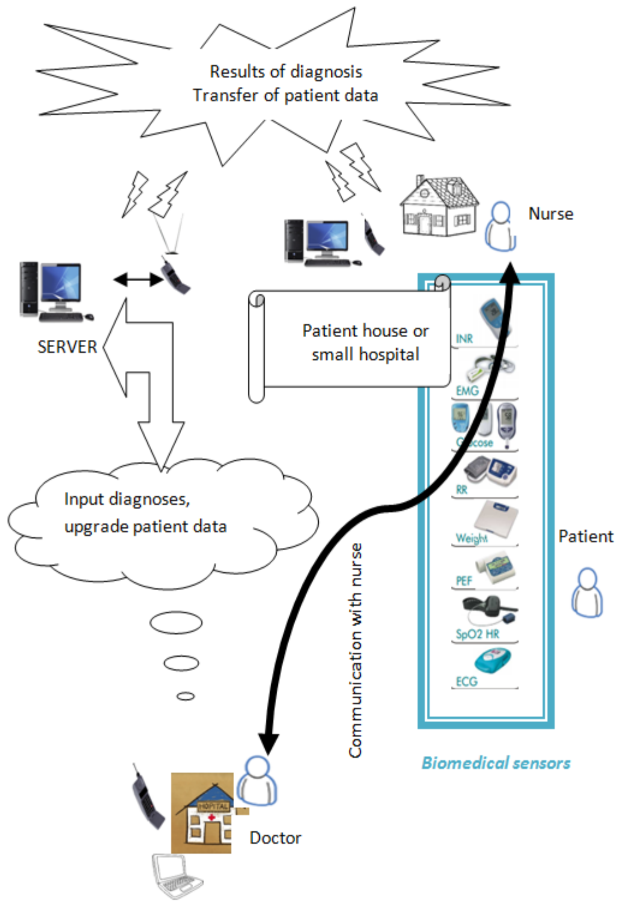

Fig.1. Remote medical diagnosis system by mHealth

The next section of the paper is devoted to the presentation of the architecture of SMS transmission system. At Section 3, we describe the different aspects of the designed and implemented software that manages the biomedical signals coding, transmission and decoding. Some of the results obtained are presented and discussed in Section 4, before the final conclusion.

II. SMS Principles and Architecture

The short message service (SMS), also called "text messaging", is based on the capacity of a mobile terminal to transmit or receive alphanumeric messages. Short messages are text messages up to 160 characters (ASCII encoded using 7 bits that is 140 bytes) and are delivered in seconds when the recipient is attached to the network even when the recipient is in communication. Figure 2 shows an example of SMS architecture.

To set up this short message service, the operator must provide one or more dedicated servers that are connected to the network. This server is called Short Message Service Centre (SMSC). Its role is to recover the sent messages and redistribute them to the recipients when they are connected to the network. Otherwise, it stores these messages. When the recipient's mobile can be located again, the network notifies the SMSC which is then able to relay the message. To send a message to a mobile phone, the SMSC uses the services of the MSC to which the recipient is attached. The delivery of the short message is guaranteed even when the mobile terminal is unavailable (for example, when it is switched off or when it is out of radio range) through the store and forward function of the SMSC.

Upon arrival of an SMS message, the user is warned by an audible signal, an icon and notification or the message on his mobile phone. By means of its Mobile Phone menu, the user can then view the short message received. The architecture of this service consists of the following:

- Gateway MSC for Short Message Service: It is a function capable of receiving a message from a short SMSC entity and to interrogate the home location register to determine the location of the destination mobile station secondly to deliver the short message to the MSC to which is attached the addressee mobile station. The serving MSC is also called Visited MSC.
- Interworking MSC for Short Message Service: It is a function capable of receiving a short message from an MSC and submits it to an SMSC.
- Short Message Service Centre (SMSC): This function is responsible for storing / relaying a short message.
- Short Message Entity is an entity outside of the GSM network that can send or receive short messages. This is a dedicated server or a personal computer. Generally, all SMSC products implement SMS-GMSC. The SMSC equipment has a standardized interface on the GSM network side. It is based on the signaling protocol MAP (Mobile Application Part).

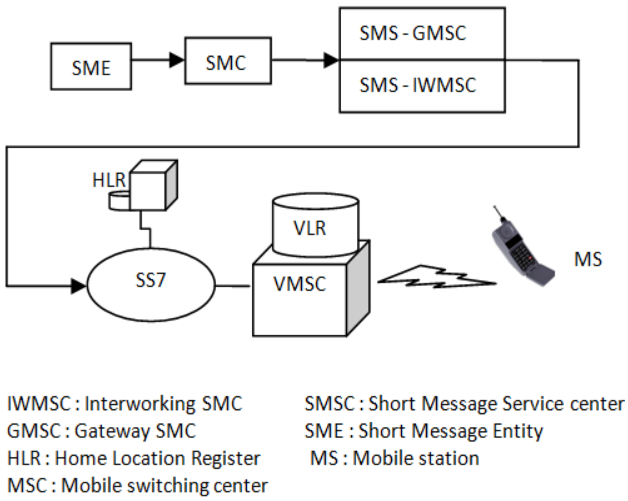

Fig.2. SMS Basic Entities

The short message transfer procedures are similar to those relating to the establishment of telephone calls, except that no speech circuit is reserved. The transmission of the short message is supported by the SS7 (Signaling System No.7) network.

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III. Encoding Biomedical Signals in Text Format

We need to transform the numerical values of physiological variables measured by the sensors in such a way that text SMS transmission protocols can support them. To this end, values of the physiological parameters are initially stored as files in the computer. We have developed a conversion algorithm of each value in ASCII (American Standard Code for Information Interchange). The flow chart of this algorithm is given in Figure 3.

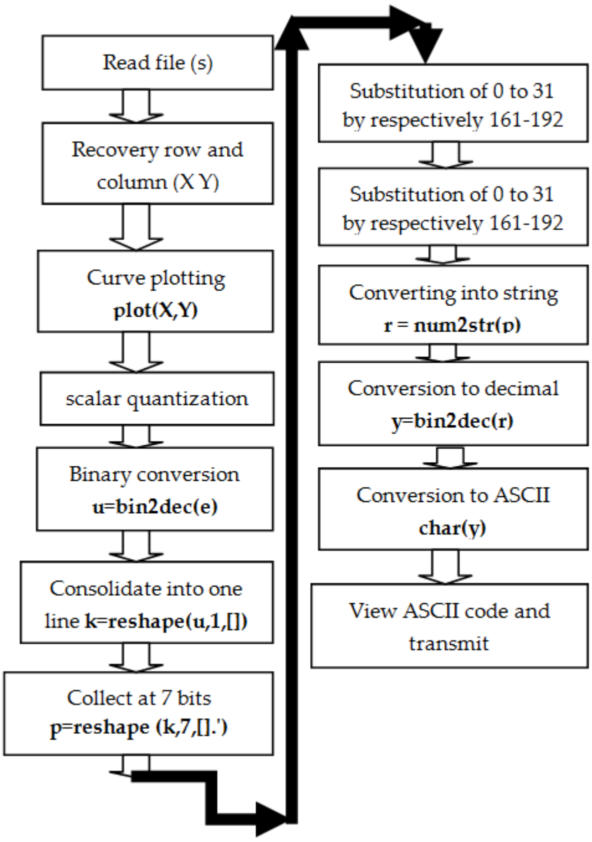

Fig.3. Flowchart of the coding process

ASCII is one of the oldest codes used to represent text in computers. It is based on the codes of table 1, containing the most used characters in English: the letters of the alphabet in capital letters (A to Z) and lowercase (a through z), the ten Arabic numerals (0 through 9), punctuation (space, comma, semicolon, quotation marks, parentheses, etc.), some symbols and some invisible special characters (space, carriage return, tab, backspace, etc.). The creators of this code limited the number of characters to 128, which is 2^7, thus, characters can be encoded using only 7 bits. This is the almost universal coding system. In the early years of computer technology, the computers were using a byte memory slots (8 bits), but they always reserved the eighth bit for parity check (that is a safety to prevent errors). Each character of a text in ASCII then occupies one byte. New standards have emerged: ANSI (American National Standards Institute) is an example that largely takes the ASCII code, and provides various extensions according to the "page code" used. Figure 4 shows an example of the page code 850 which is widely used.

Table 1: The ASCII code

code	0	1	2	3	4	5	6	7	8	9
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT
10	LF	VT	NP	CR	SO	SI	DLE	DC1	DC2	DC3
20	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS
30	RS	US	SP	!	"	#	$	%	&	'
40	(	)	*	+	,	-	.	/	0	1
50	2	3	4	5	6	7	8	9	:	;
60	<	=	>	?	@	A	B	C	D	E
70	F	G	H	I	J	K	L	M	N	O
80	P	Q	R	S	T	U	V	W	X	Y
90	Z	[	\	]	^	_	`	a	b	c
100	d	e	f	g	h	i	j	k	l	m
110	n	o	p	q	r	s	t	u	v	w
120	x	y	z	{	|	}	~	DEL		

NUL Absence de caractère,blanc,espace
SOH Start of Heading : début en-tête
STX Start of Text
ETX End of Text
EOT End of Transmission
ENQ Enquiry Demande
ACK Acknowledge, accusé réception
BEL Bell, sonnette
BS Backspace marche arrière 1 caractère
HT Horizontale Tabulation
LF Line Fed retour à la nvelle ligne
VT Vertical Tabulation
FF Form Fed, passage page suivante
CR Carriage Return, retour chariot
SO Shift Out caractère suivant non std
SI Shift In retour au caractères std
DLE DataLink Escape chgmt de signific.
NAK Negative Acknoledgment
SYN Synchronous, caractère de synchro.
ETB End Of Transmission Block
CAN Cancel annulation de la donnée précédente
SUB Substitute remplacement
ESC Escape caractère de ctrl d'extension
FS File Separator
GS Groupe Separator
RS Record Separator
US United Separator
SP Space Espace
DEL Delete, suppression

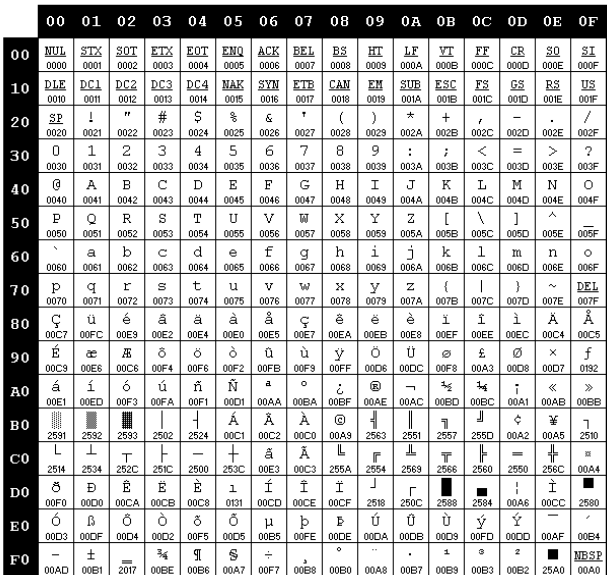

Fig.4. Page code 850

The encoding process begins by reading the file containing the patient's physiological data. These are tables where the first column is usually the vector of time; the other columns are either the different leads of the same signal, or the values of several other parameters that were recorded simultaneously. We then carry on the quantization. The quantization operation consists in bringing the real numbers values of the biomedical signals to integers between 0 and 127. these integers are converted into binary numbers before being grouped into 8-bits words. Those words that correspond to the decimal values between 0 and 31 are the invisible ASCII characters. We added the decimal value of 161 to translate these special characters values in the range of 161 to 192. The 8-bit words coded in ASCII are transmitted using SMS protocols. In Figure 3, some Matlab syntaxes that we used in the experimental phase are provided. Figure 5 is the block diagram of the decoding process. One can find the inverse operations to those described in figure 3.

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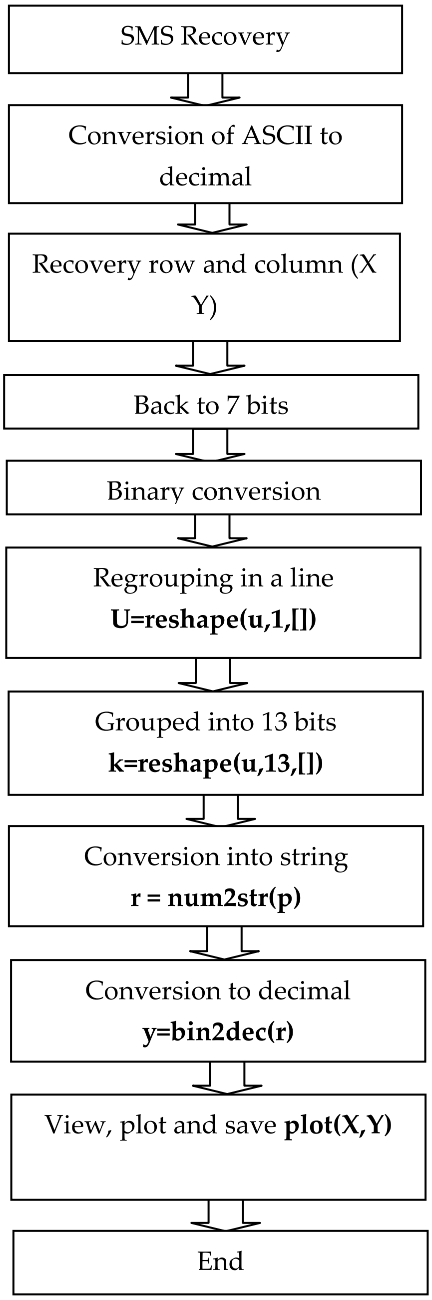

Fig.5: Decoding SMS to obtain Biomedical signal

IV. Results and Discussion

We conducted tests using biomedical signals from [16]. In the experimental phase, we have limited durations of those signals to one second. It can be observed in Figure 6 at the top, a portion of ECG signal transmitted and three versions of the received signal in different situations of coding. The original signal is that of 6-a. The situation of figure 6-b is where the numerical values obtained after quantization have been directly encoded in ASCII. Many distortions appear in the decoded signal. After a deep analysis of the whole process, we understood that the deformations were due to certain ASCII characters that are interpreted by the operating systems as instructions. Some of these characters are: NUL (No character: 0 in decimal), BS (Back Space: 8 in decimal), LF (Line Fed: 10 decimal) and CR (Carriage Return: 13 in decimal). If we take the example of BS (8 decimal) which is the back space, when this character is transmitted, the operating system interprets it and automatically deletes the preceding character. Figure 6-c shows the situation where we have considered the replacing of some of the characters supposed to be causing distortions by those that immediately follow them in decimal representation. Thus, 0 is replaced with 1, 8 is replaced by 9, 10 is replaced by 11 and 13 is replaced by 14. It will be appreciated once again that deformations persist and the decoded signal is not utilizable medically.

We felt that all of the first 32 special characters of ASCII encoding for control were not appropriate for our application. The operating systems and the transmission protocols consider these characters as instructions. This is a great problem because the transmitted signals always incorporate serious undesirable changes. We therefore decided to replace the 32 first characters by other characters that a priori do not lead to a problem. The reverse process is carried out at the reception. Thus we worked with 7 bits (128 characters) by replacing the 32 special characters of ASCII code by some of the extended ASCII characters. The characters 0 to 31 are replaced by those of 161 to 192. Once the replacements are achieved, the signal is encoded and transmitted. At the reception stage, the reverse operations are performed such that the numerical values ranging from 161 to 192 after decoding are brought by translational values between 0 and 31.

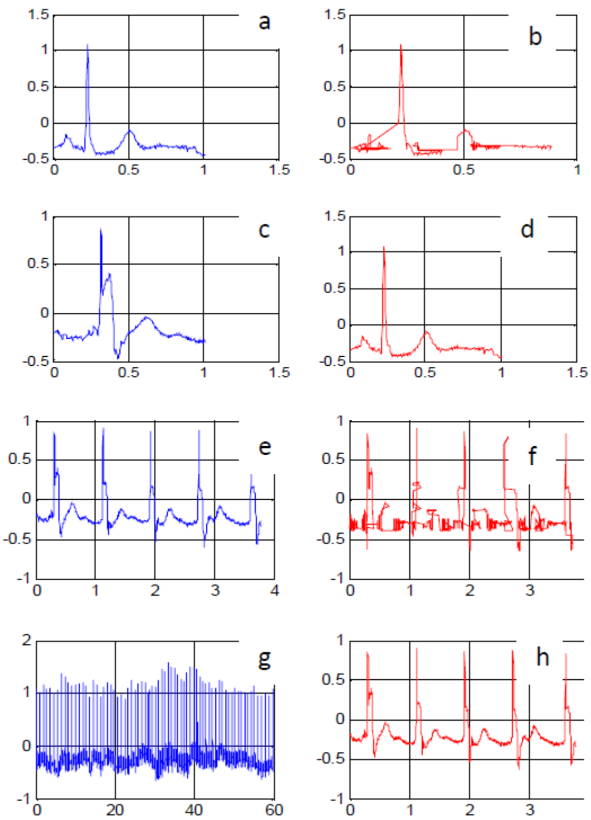

Fig.6. Original signal and the received signals using 8 bits non optimized and optimized ASCII encoding for SMS transmission

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The result is shown in FIG 6-d where the received signal after decoding is identical to the transmitted signal. Figure 6-e is another original ECG signal of nearly 4 seconds duration. The signals shown in figure 6-f, 6-g, and 6-h are the retrieved signals after decoding the transmitted SMS in the same situations as respectively in figure 6-b, 6-c and 6-d.

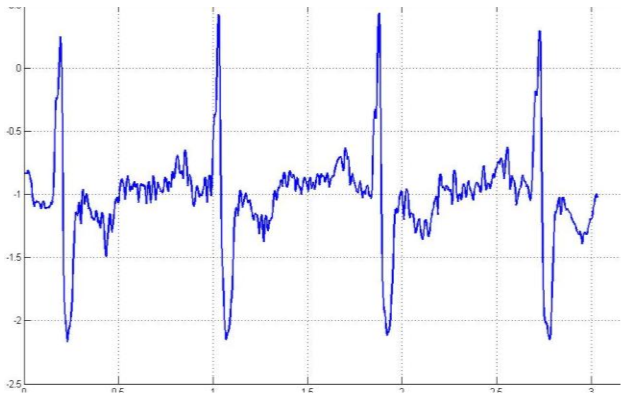
Figure 7 shows an ECG signal consisting of 1092 samples that have been transmitted by SMS (blue). The received signal in red color is also shown as well as the ASCII characters set that were generated and used for the SMS transmission. The application generated 4056 ASCII characters for this signal. Since each SMS message contains up to 160 characters, it follows that it takes 26 SMS messages for transmitting the signal mentioned above. An SMS message costs about 4 cents US. The global cost of the transmission of the signal of Figure 7 is therefore US $ 1.04. This amount is paltry when compared to the medical interest that it brings to the patient. In figure 8 is shown another example where 1182 samples of electromyogram (EMG) have been transmitted using 28 SMS for a cost of US $ 1.12.

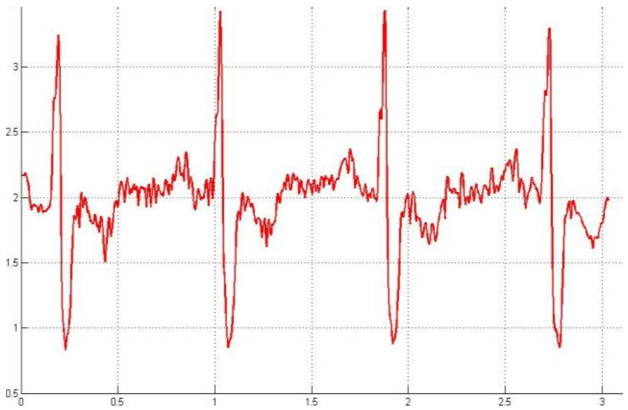
We conducted several tests and simulations. We coded into ASCII characters, many other physiological signals, such as electroencephalograms (EEG) and respiratory signals all from [16]. The results were very satisfactory. We also made several field trials by connecting mobile phone terminals to the computer in order to send through SMS, texts generated by the ASCII encoding of biomedical signals. The SMS received by other mobile phone terminals were transferred to computer before the decoding and the display operations. The results were also perfect. Our system is very robust and reliable.

This application falls in the mHealth telemedicine technology. It can be used in continuously medical analysis and automatic recording of patient physiological parameters. This technique can also contribute in the development of home hospitalization, particularly in cases of older people. This also helps to avoid unnecessary or unwanted hospitalizations for the patient. The interest is even greater for low-income countries where the lack of specialist doctors is garish.

V. Conclusion

We believe that we have achieved the goals we set ourselves, namely the development and implementation of applications that encode biomedical signals into ASCII characters, transmit the texts obtained by SMS and realize the decoding of the SMS messages received to restore the original values of the physiological parameters. The SMS technique that was initially designed for text messages has been exploited for remotely transmission of very complex biomedical signals. This work is a small contribution in the development of telemedicine systems. Its interest is well established.





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¹^1Dc)G¤¯&¿L@º§2µdAI3´&(LSº,2deaKs¹&2-gºT30fyN#¾&<-zºz4¡hºPS"§EM¯»"4Li1S´'§O®!»H5¹jQUC+FY®5»l5hkiX¤0FbMH¼µ68m¢Z35FlM\¼<7¥n!\s:&v®o¼d7
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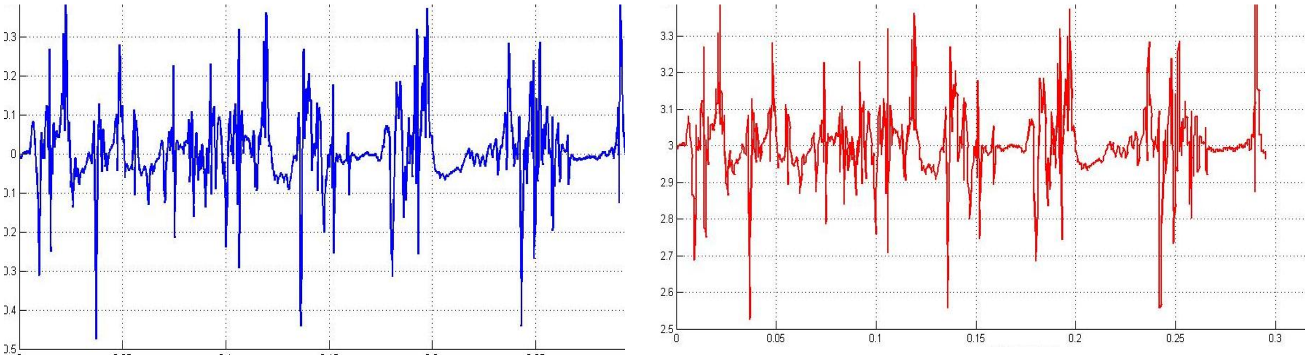
1@c¢2¤-©X¶±9!¢B+¥V«L¸©.±a!BC°§¿¬D´(!P1`YAo¦v¯T"(>0m!8B{§2ª|«H£/u_z@'¢¿¥,¨8§±¥_~?V□¢|¼w¸loWÀ*?§□¢□t¢¸zodÀ*>£|¾z¤w¸n/R_
>r□¢}c}7s/UÀ·>"|mx;oWd/za¬DM¯§"TH9ª1|$·JE½¯Gm%JNtF&$Eb}ee¬(6'LÀX½/|_9<2q5Xk ·J-
FZy6»nui¬k¹·1De5Pc1W¥¯A]g<PyErkcgBO²^7=H|Ey3u'oOY^x<Fw1mCawRoC_%?»~5{Ks7T°¦¾g;bx¢p{`GA°¡¿¡;&uAh¼Mw¼n<]³:`v²mC[G/nK]¤9>r1c;Fw°.7]0;½v9m
CW'%n?½e9"r}fSQW*nl¾v;vy®r¼h¸Wo4^}>¹|Eu{cg@°,_9@'££¤\¥w|°kÀR?@□¢|kwgpoiÀf?@~q|¼zgpo_À9?±})x¬j¨`/i
'A3£f¥,¡Gr°H^x=R|1y[tWfoF¿s=z|Y}´}7}/u_R>||Ex;tWtO□
ª?V~q|kwgn/UÀ¼>¯{Mx;u'r°kÀu?j□y□S~Ww°pÀ`>|}9zsz(¢±"`|B¤¤6¤3□s/a_V?@□i□+}7tOf_V?A¡³¡$§¹²0¼
"@O¢Z§D®X½PEaÀB?¥~ª¥³©+P^a=BI¥B§½©©¨0¹`TB5§2°$"xB±ha¢?t~!|C|h£0¹`,@E¡&¡s~Wpo@^K=2{9x¬s7loa_M?$~q□¥¥(¯p·
"@´¡²□t¡Gw°pÀk?@□¢{Kr¸`/7¿n>"~r¥¥·8M1^$HJY·>,TV°2R~'³Po%*J}¢y61¶^}8£hªE»~EqKTW$.\]²82keQ+¹V',DYY5Jx&®,T»47¿quk#^¸F/«¿#<Zz°vKo¨ao,^#<¡y!uKp¸
`/C^n=*z¦s¬d7K/µ¿-<FxQq#bGBN}]g;Dv9lsWw1¯]¾+:Lt]h¼O¸¾¯/_9JsegKLW²nº\»8frYfSMw¾¯5½e9Ts¶g#Pw)N]¾I;8vMmC\'=O¨^1=-zUw¼r¸h°PÀ-#

Fig.7. Transmission of an ECG signal through SMS using ASCII encoding: Original ECG in (blue), received signal (red) and ASCII characters generated



#°PÀ >@}¢z#tGi°TÀ(>P}!zCuGk°VÀ0>`}A{¤v¨m°ZÀ4>p}a{Cw¨n°^À<>x~¢|¤x¨p°`ÀD?©~²|Cy¨r°dÀH?¹~1|cz¨t°hÀP?
~Q}#zGv°lÀX?0~a}c{Gw°pÀ`?@□¢~¤|Gy°rÀh?P□!~C}¨{°vÀl?`□A□¤~¨|°zÀt?h□a□C□¨~°|À|?x□r¡¥¡©¡±¡ ¥@ª¡³¡$¢©£±¥ ©@°¡2¡d¢H¥±© ±@!¡R¢$£H¦±-
¹@1¡b¢d¤H¨±¯ @A¢££¥¥Hª±³ $@Q¢"£D¦©¬±· ,@Y¢B¤¥§©-±» 4@i¢R¤D¨©¯±½ <@y¢r¤d©©±± @Aª£³¥$©H³±$ HA²£2¥dªH´±(PA!£B¦$«H¶±* XA1£b¦D¬H¸±.
\AA¤£§¥-©°±2 dAI¤"§D®©»±6 lAY¤2¨¥¯©½±8 tAi¤R¨$°©¿±< xAy¤r¨d°H
±@!¡B¢¥³©$±H!±D!©B²¥"©d²H#±F!±B!¥Bª¥³H%±J!µB1¥bªD´©'±N!½B9¦£«¥µ©(±R!$BI¦³«D¶©*±T!,BY¦2«d·©,±X!0Bi¦R¬$·H.±\!8Bq¦r¬d¸H/±`!@C¢§£-$¹H1±b!HC²§"-
D°H3±f!LC!§B®¥»©5±j!TC)§b®D¼©6±n!\C9§r¯¥½©8±p!dCI¨³¯$¾©:±t!hCY¨2¯d¾H<±x!pCa¨R°$¿H=±|!xCq¨b°dÀH?±~"¡D¢©£±¥
HA²£"¥D²©"±D!©C²§"-D°©B²¥"©D²«"µD)©R²D#©F²-"½D9©r²d$©H²±"
DIª³³$$HJ²µ"(DQª2³d%HK²¹"0DaªB´$&HM²»"8DqªbD'HO²¿"<E¢«£µ¥(©Q²""DEª«"µD)©R²&"LEº«2¶¥*©T²("TE)«R¶$+©V²,"XE9«r¶d+HX²0"`EA¬³·$,HY²4"hEQ¬"·d-
H[²6"pEa¬B¸¥.H]²:"tEi¬b¸D/©_²>"|Ey-£¹¥0©`²B#¥Fª-³¹D1©b²D#-Fº-2¹d2©d²H#±F)-Rº$2Hf²L#¹F1-rºd3Hg²P#
FA®£»$4Hi²R#(FQ®"»D5Hk²V#,Fa®B¼¥6©m²Z#4Fi®b¼D7©n²^#<Fy®r½¥8©p²`#DGª¯³½$9©r²d#HGº¯2½d9Ht²h#PG!¯R¾$:Hu²l#XG1¯b¾d;Hw²n#`GA°£¿¥<Hy²r#d
GQ°"¿D=©{²v#lGY°BÀ¥>©|²z#tGi°RÀD?©~²|#|Gy°rÀd@ª¡³¡$¡Hª±³ $@I£³¥$©H²±2
dAI¤³©$±H!±B!$BI¦³«$¹H1±b!DCI¨³¯$½HA²£"¥Dªª³³$$HI²""DEª«³·$,HY²2#¥Fª-³¹$4Hi²R#$Gª¯³½$8Hy²r#dGI±³
$@I¢³³$$HI²³$$HI²³"$dII´³&$PI!³B%¥JI¶³*$TI1³b%DKª¸³.$\I9´£&¥Lª¹³2$dII´³&DMª»³4$lIY´2&dNª½³8$pIi´R'$NI¿³<$xIq´r'dOIÀ³@%¡J¢µ£($PI!³B%©J²µ"(DQI#³F%-J!µ
B)¥Rª%³J%µJ)µb)DSª&³N%½J9µr*¥Tª(³P%$JI¶³*$Uª*³T%(JY¶2*dUI,³X%0Ja¶R+$VI-³\%8Jq¶b+dWI/³^%@K¢·£,¥XI1³b%DK²·",DYª3³f%LKº·B-¥Zª4³j%TK)·R-
D[ª6³l%\K9·r-d\ª8³p%`KI¸³.$\I:³t%hKQ¸2.d]I;³x%pKa¸B/$^I=³z%xKq¸b/D_I?³~%|L¢¹£0¥`ªA´£&¥Lª¹"0DaªB´$&-Lº¹21¥bªD´©&µL)¹R1$cªF´-&¹L9¹r1dcIH´±&
LAº³2$dII´µ&(LQº"2deIK´·&0LaºB3¥fIM´»&4LqºbDgªO´¿&<Ly»£4¥hªP´"&DMª»³4DiªR´$&HMº»24djªT´(&PM)»R5$jIV´,&XM1»b5dkIW´0&`MA¼£6$lIY´2&hMQ¼
"6Dmª[´6&lMa¼B7¥nª]´:&tMi¼b7Doª^´>&|My¼r8¥pª`´@'¥Nª½³8$qªb´D'©Nº½28dqId´H'±N!½R9$rIe´L'¹N1½b9dsIg´N'
NA¾£:¥tIi´R'$NQ¾":DuªkV',NY¾B;¥vªl´Z'4Ni¾R;Dwªn´\'<Ny¾r;dxªp´`'@Oª¿³<$xIr´d'HO²¿2<dyIs´h'PO!¿B=$zIu´j'XO1¿b=D{Iw´n'\OAÀ£>¥|ªy´r'dOIÀ">D}ªz´v'lOYÀ2
?¥~ª|´x'tOiÀR?$□ᵖ~´|'xOyÀr?d□J¡µ¡(¡P¢ ³@%¡J¢µ¥(©P² "@e¢J¤µ§(±P! BA¦£J¦µ«(µP1
bAE¤«¨µ¯(½P9!£B¦¥«©µ³($PI!³BE¦««µµ(,PY!2Be§«-µ¹(0Pi!RC%§J¯µ½(8Pq!rCe¨J°##N¨¼z8½oi`3C'§N¸½&8lqibsEg¯N!½.8\r)cSD'¬NO¾¿<TyIv3lgEOª¾§9|liY3&&LL¦¸
b%¥J99³ug½O¢½&7dsyes?'´Oº¿F>U¡Yxsq'»P¤º«I4Uª#sL&□M)¼¯=½{ªfSN'?N□¿³<µvils\'3N{¾~>,}«©t³'{Oy%zC,xJ-U¥iUP?
^:Luºu´mg¢MuºN54dyHS¡f-M¬»*7doIW´'faMC»«4½gºPS*&VM9»f6½l9V3+f^MA¼*6Tnª\S?f□N´½68-pº]s:foMi¾§:µ{9w3®&ªFe®:'|QifSQ(©OY¾:>µpI_s-
fuO¬¿·8lq9ZS7gªN´»z6¥o)_´Fg®N+½N9dsªh3Ng"NI¾n;l{Yw3wghM=½v@]£Z(44glOQ
§@,uinSSg"M¼»26Dmª\´5fcMG»r5tl9Xs4&kMK¼£9¥r9~3wfÀNg¿z=twªm3?f~MA¼§5<kºT3(fVM/¼§5tmªZS0&cM#»F1\c)As¬&=M¢¼§6,nªY3*&WM9»n6Tm9]s:&y
Mk¼r7Toy_´Eg®N9½r:\tydsH&,LS¹.1DkiX´Eg¬NO¾³<µwYdSS'DO¾¾n;,k:¼³\e2Lmºv:4tIjsR'¶N'½v9dtºh3L'½N'½J8DqiisOg)NW¾»:4t)hSq'6M¢¼£;Dwy}´hf,LE¸"2<oi_
s^g=N¨½§54hY]sEf`N%¼¯6|tºg34&fM/¼¯0-`ºRS&g¸N!»Z6\uIl47h½LE¾j>,|Y□T¢gÀN+º>3\qªc3f'NOKÀ¿=t{inS['ªN´»Z5$n)]´¯f´J3¶·/l`)_sB'TO-
ÀZ>TqilsC'¥M_½&>T}Z£´□&□M9¿R05¦j222&·M[¼R>½~yl3Ug¬N?¾V;Dv9mSX',Nc¾.;¥uIh3PgªN´¼~8Du9k´b'1LiºN7¥m9JS¹fmMa¾V;,wyh3cgIP®
6=$yj*T7g3O1'NN]©j°3^g6N9¾³9dsI`s?fcMK»n5\hYQ3(fMM%»23\gYR´$&QMÀ»Z54j)U´&&MM¦ºz4diITS*&EM¨ºN3$eIL3!&CM¼»66½l9]3;g¤N¤½¯8½ny^3G'³O7À
J:LsI§qg$?I¸½J9}²*%SX':P/¿zC¦¦i|4¦(3Q- BAU£*¥´4&^M}½§:-t)bsAg$NI
.@-e)p´~(¡O=¿v8$oyI´²%hKI·£,\dªI´#fEMA¼§84piYS:'¶N+¾§9Df»¯RJ%«K[¸N7µnYb3D&wMi½¯7|qªa´<fzMe¼J6|mY]39&uMk¼f7<oy`3^g?L?º>6¥l9a´B'ªN´½³8½qªaS
@g¢M}½§7Loi^3?fzM□½¯7|pIa´@g§N¤½"8$pibsEg©N²½68\pib´B'©Nª½"8$qª`sD'¤N²½³8LpIa´?g¢Mo¼j7<nY^S;f|My½68tsYh3M'»O¬¿¿=-xYt3e'@O¾¾j;½aiARCe¼I
%³:-L[yS´(g@O¬ >D®¡Z§SrgcP¼ 6D¶§)q3b&\M/¸³.thyZ´®f²M¦»¯9Tsyy3lfoMy¾b;4jyS3G'¸OUÀ2FU¨IO3$)IR_µ¿9µkIY3Zg:O7¿«Bu¨z©s{hLRi *;®³»'T□i&P¸
»;-vºos_g6Nm½:8to)_´1fcM7»z5<k9US+&YM3»"4DiYS3)&RM/»Z4liyQ3#fQM¼»F5µiYSs*&RM/»R5\kºUS,f\M=»n5tlºWS1faMM¼·6¥lºW´0&YM7¼§6-m9Zs9&rMs
¼f8½pºbsDg¯N¾½V9,oi_SD'©N!½67To)Zs5&rMe½¯8½qªb´@g¥Mo¼^6Tm)\´9&□M□½³8-nI\S4&hMo¼f8DqªesJgÀN;¾«:-qºb3?g¢N%½N9lsykSW'¹N/»Z5µm)ZsDg¬
N9½r9DsIj3TgBO¬À*?µz9q´0'¾Qª"FJ-¯9}T«'XO'¿«<ds)d´5&tN?¾«9¥qi_´='&NOÀ"><ZY0qg#VJU¶R3Lhªds0"Ng»"3lnª]´b'6P¢
·D®©)z´G'^Qqµ«'lVy.rtglP/»24½lYZTD)&P!Àr7Lyº]36g"NM¿N9,vinS|h¢O3¿N8\t)d´I&□N¨¸&>DX94´3&jLm»^:$tins]gXO1¼.6,hªT3Fg±NC½~9,ryd´I'®N¾½J8tsYnS#f
9M/»^7|oiaSC'¢N¨¼z7Loi_S<f|Mo¼^7doº_S?&zM}¼f7toº^3?&zM}¼z7To)`3>'¢N¤¼z7|p9`s?&|N¨½³8-oya´?g¤M}½¯7|o)_S<fzM□¼z8½oia´D'¤N¨½.8lqºbsG'®Nª½"8-pºa
SD'¥N®½B8lr9dSL'¹N¸½&7dpºe3Jg&N?¿£<µ{Z¡´¦f¬T)(NK¦¶Z©t°'BO¢¾¿:<qYbs=&|Mo¼j7,ny\´8&e#

Fig.8. An EMG signal transmitted through SMS using ASCII encoding: Original signal (blue), received (red) signal and the generated text.

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