Applied Engineering
2019; 3(1): 65-70
http://www.sciencepublishinggroup.com/j/ae
doi: 10.11648/j.ae.20190301.18

Wake-Up RF Communication Node Design and Use for Communal Living and Emergency Alert in Remote Areas of Developing Countries

Pierre Tsafack[1], Jean Kamdem[2], Bruno Allard[3]

[1]Department of Electrical and Electronics Engineering, University of Buea, Buea, Cameroon

[2]Department of Electrical and Telecommunications Engineering, National Advanced School of Engineering, Yaounde, Cameroon

[3]Department of Electrical Engineering, Institut National Des Sciences Appliquées De Lyon, Lyon, France

Email address:
pierro_tsafack@yahoo.com (P. Tsafack), kamdem.jean.k@gmail.com (J. Kamdem), bruno.allard@insa-lyon.fr (B. Allard)

To cite this article:
Pierre Tsafack, Jean Kamdem, Bruno Allard. Wake-Up RF Communication Node Design and Use for Communal Living and Emergency Alert in Remote Areas of Developing Countries. *Applied Engineering*. Vol. 3, No. 1, 2019, pp. 65-70. doi: 10.11648/j.ae.20190301.18

Received: May 18, 2019; **Accepted**: June 18, 2019; **Published**: July 2, 2019

Abstract: We proposed in this paper a free communication system for restoring a communal living and a minimum autonomy of operating in remote areas of developing countries. This system also intends to restore the return to local values, to strengthen the links between the populations, and to facilitate communication during epidemic or arm robber's attacks in remote localities of developing countries; it also helps in a follow up of old people. Commercial Off-The-Shelf (COTS) components are used for global system nodes design. A covered area of 260m is reached and can be extended with dedicated additional antenna.

Keywords: COTS Components, LAN, RF, Security, Epidemic Alert, Communal Living, Free of Charge

1. Introduction

The advent of telecommunications and multimedia in developing countries has facilitated the means of communication between populations, but has also seriously undermined the living together between the populations and especially in village localities. Among telecommunications and multimedia consequences, we can also mention the loss of power of traditional authorities, the strongest belief in external information than local, exchanges and local sharing increasingly limited.

All these failings call for a stronger presence of the central government which is struggling to take matters into its own hands. People are then manipulated and that is leading to a hatred towards the others, sometimes going as far as killings and massacres [1-4]. Basically, mutual knowledge of the populations that was before a warranty of their security needs to be re-established. Other types of emergencies like epidemic diseases being observed in most of developing countries need also to be addressed. Although there exist toll-free numbers for alerting the concerned service in case of such incidences, such numbers are usually jammed and inefficient, or there will be no means to either localize or reach the victim site. There is a need to facilitate, in case of epidemic disasters like Ebola in RDC or epidemics of cholera often occurring in developing countries, the contaminated houses to easily inform and ban the others from visiting them [5].

We proposed in this paper a free communication system based on COTS components which can help to restore communal life and a certain autonomy of functioning in remote areas of developing countries; the proposed system is also intended to strengthen the links and to restore the return to local values among the populations of those isolated localities of the developing countries.

As far as a global security is concerned, classical surveillance systems which don't even exist in such remote areas are generally based on video recording of the scene that occurred in the area of interest. Nevertheless, there are some limitations associated with video surveillance in situations of obscured vision (for example a foggy weather); it's difficult to deploy video cameras in areas where accessibility is limited or restricted [6]. Audio surveillance on the counter part is adequate for cloudy weather scenarios since it requires just the acoustic information conveyed by sound waves. Sound sensors can capture audio information that may be difficult or impossible to obtained by any other means; and finally, wireless acoustic node can be installed and easily displaced in any position thereby increasing the monitoring area [7].

This research work includes a design and implementation of a wake-up system to create awareness of a locality under observation through audio information in the area of interest. The modulation scheme adopted for the audio signal is phase locked loop and a wake-up unit is implemented by a microcontroller of microchip.

The first section of this work gives a review of local communication techniques and security in remote areas of developing countries, with their advantages and drawbacks. The second section lays out the various methods used to cover the full functionalities of the system; these include the hardware and software interfaces as well as the used algorithms. The third section reveals the implementation, tests and results obtained from this system. The last section discusses the weaknesses and strengths of the system as well as the work that can be done to improve upon the system functionalities.

2. Review of Local Communication and Security Techniques in Remote Areas of Developing Countries

2.1. Local Communication

The use of technology to communicate is all over the world in today's society, including remote areas of developing countries where it has banned people from their traditional means, and so almost stopping the population from former community life. Emergent technologies have given rise to several communication tools employed by people to pass an information. This include, mobile and fixed phones, tablets, internet, radio and television sets and many more others.

2.1.1. Use of Mobile Phones

Mobile phones are being used in different sectors as a channel to convey information. Most common and public information in developing countries are conveyed through mobile telephone companies and less and less from individuals because of limited communal life. For instance, through text messaging, public information such as vaccination campaigns for infectious diseases use to be disseminated by communication companies [8]. Otherwise for information like epidemic threat from local sources, individual mobile phones are a poor mean to contact the entire local population because of communication credit and none availability of all contact numbers. In all, the use of mobile phones has the overall effect of spoiling the former communal living where the population was sharing same information and orders from the same source. To sum up, individuals in remote areas use phones on daily basis to keep in touch mainly with abroad relatives losing the communal living and trust to local neighbouring and authorities.

2.1.2. Use of Internet

Nowadays, social media serves as the one of the main channels through which external information reach people in remote areas. This is made possible thanks to internet. The internet has bridged the geographical gap between people due to the rate and ease at which information circulates over the internet [8]. Internet services such as emails, WhatsApp, VOIP, video calls and other multimedia services facilitate the way by which people are addressed [9]. But limitations of such communication mean in villages include lack of internet credit, need of android phones and limited use ability of majority of the population.

2.1.3. Use of Radio and Television

Radio broadcasting was the first solution adopted to address the general public [10]. Today, radio sets permit the reception of information broadcasted from the various radio stations. In Cameroon, government officials use the national radio station to address the population. Also, radio stations serve as a platform to pass a communique, to advertise products, to pass announcements and sensitize the public on health, education and social aspects. Amongst limitations of such means we can highlight very low holding of radio and TV sets in village localities, poor listening of radio and TV information and no electricity or very poor electrocortical network coverage in developing countries.

2.2. Security

In general, security systems are based on traditional means such as fence, dogs and self-defence groups. The use of dogs and fences are mainly for individuals; defence groups are usually set by the community and only operate by night. The limitations of such means are really much, giving that self-defence group members had not received any training for such tasks; they also usually take advantage to solve personal issues like what just happened recently in some of African countries where the all population of entire villages was slaughtered [1].

3. Block Diagram, Methodology and Design

The basic design procedure adopted in this work consists of COTS components analysis, test and characterization for Audio communication system.

3.1. Node, Global Block Diagram and Description

3.1.1. Node Description

Figure 1 is a block diagram of a global node. We used a digital PLL to modulate the audio signal into a square wave carrier signal. The RF Transmitter takes care of the second modulation and transmission of the PLL digital signal by RF propagation through the antenna. For the receiving end, the RF Receiver picks up the RF transmitted signal, extracts a modulated PLL square wave signal which is then demodulated so as to recover the information.

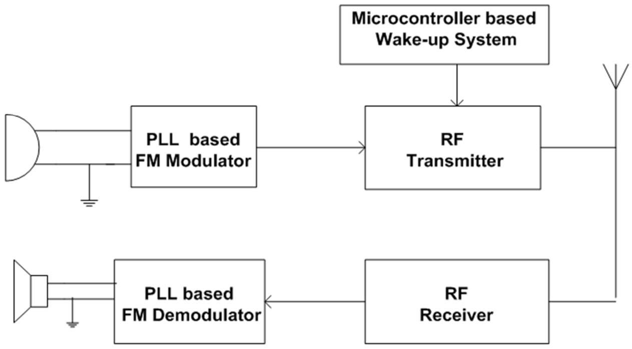

Figure 1. *Block diagram of a global node System.*

3.1.2. Illustration of an Implementation in a Remote Area

As illustrated in Figure 2, the proposed system provides an audio network of a monitoring area. The communication links represent the transfer and reception of audio information. In addition to houses, samples of RF wake-up nodes can also be installed to monitor some suspicious locations of the village.

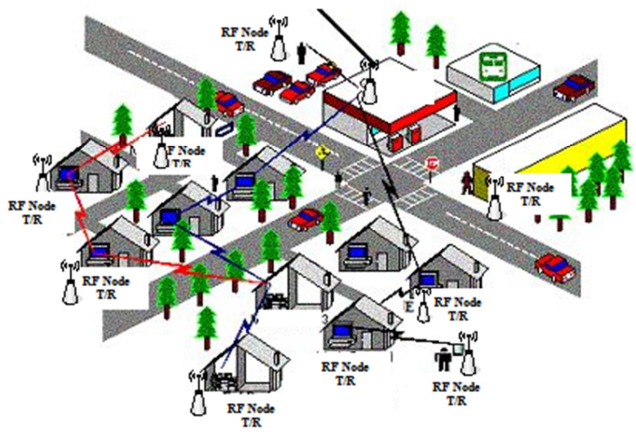

Figure 2. *Illustration of an implementation for security and communication in a local area.*

3.2. Methodology and Circuits Design

The proposed circuits are shown on Figure 3. The Wake-up RF node system consists of two parts; PLL 4046 IC based audio modulation and TX/RX transceiver. The microcontroller-based wake-up aspect is optional and deserved for the monitoring of sensitive areas for security purpose; this can also help in a follow up of old people.

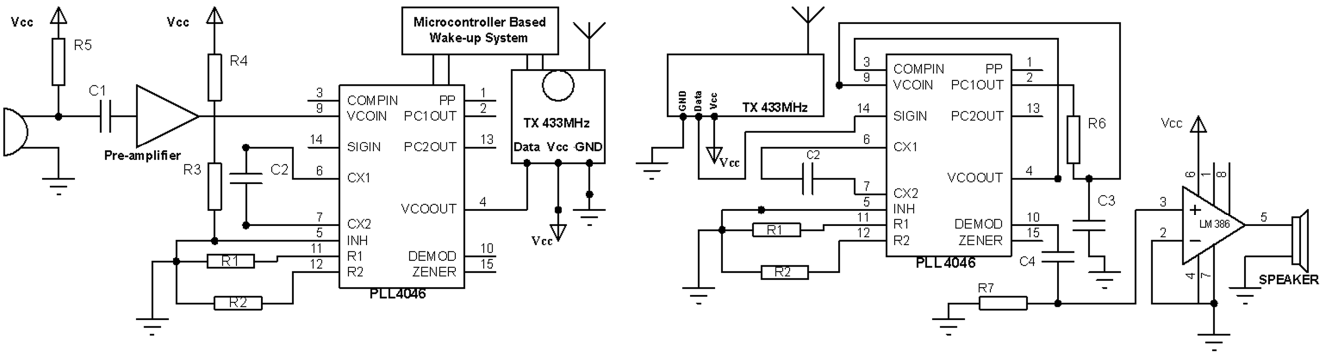

Figure 3. *Wake-up RF Node circuits.*

The RF transceiver (XD-FST and XD-RF) module is used for RF transmission at 433MHz [11]. Its communication range varies from 75 metres (in-building) to 260 metres (on open ground) and can be prolonged by the use of additional antenna.

The LM386 based amplifier is used to amplify the audio signal at the receiver end [12].

3.3. Mathematical Considerations

Thanks to the use of PLL 4046 IC datasheet, parameters such as frequency offset, carrier frequency and free running frequency have been determined so as to perform FM modulator and demodulator functions [13].

3.3.1. Mathematical Considerations for PLL Based Modulator

A. Offset frequency of the VCO.

For the integrated circuit PLL CD4046, the offset frequency is determined by the value of capacitor C2 and resistor R2 (pin 12 of PLL 4046 IC); that can be expressed by (1) [13-15].

$$f_{\text{offset}} = 1 / R_2 C_2 \quad (1)$$

The PLL integrated circuit used in this application is the CD4046B, which consumes only 600μW of power at 10 kHz, a reduction in power consumption of 160 times when compared to the 100mW required by similar monolithic bipolar PLLs [13]. We then chose an offset frequency of 10kHz so as to minimize a power consumption of the PLL circuit at zero input signal and also during the standby status.

Considering therefore $f_{offset} = 10kHz$, we will need for instance $R_2 = 100k$ and $C_2 = 1nF$.

B. Output frequency of the VCO.

The output frequency f_{VCO} of the VCO is a function of the input control voltage vc, external resistor $R1$ (pin 11 of PLL IC 4046) and capacitor C_2 as indicated by (2) [13-15].

$$f_{VCO}(vc) = 0.16 v_c / R_1 C_2 \quad (2)$$

C. Center frequency of the VCO.

The VCO generates a center frequency f_{center} expressed by (3), when its input control voltage is biased at half of the supply voltage V_{DD} [13-15].

$$f_{center} = f_{VCO}\left(\frac{1}{2}V_{DD}\right) = 0.08V_{DD} / R_1C_2 \tag{3}$$

Considering a supply possibility of nodes with existing batteries of 9V (i.e. $V_{DD} = 9V$), $R_1 = 10k$ and $C_2 = 1nF$, $f_{center} = 72kHz$.

D. Free running frequency of the VCO.

The free running frequency f_o is the frequency generated by the VCO in the free running state. Modulations and demodulations are basically done around that free running frequency of the VCO which stands then as a carrier signal of the PLL system; it can be expressed by (4) [13, 14].

$$f_o = f_{center} + f_{offset} \tag{4}$$

Considering the f_{center} and f_{offset} discussed earlier, a carrier signal of 82kHz will modulate the audio signal from the sensor.

E. Maximum VCO frequency.

The VCO generates a maximum frequency $f_{\max}$ when its control voltage is equal to the supply voltage V_{DD} [13, 14]. Considering equation (2) and a supply source of 9V, the maximum VCO frequency can be given by (5).

$$f_{\max} = f_{VCO}(V_{DD}) = 144kHz \tag{5}$$

3.3.2. Mathematical Considerations for PLL Based Demodulator

To demodulate the PLL based FM signal, amongst considerations such as capture range and cut-off frequency of the PLL loop filter, the carrier frequencies of both modulator and demodulator should be the same. We used the same R_1, R_2 and C_2 values for both PLL based FM demodulator and modulator so that the carrier frequencies remain the same.

PLL loop filter and capture range

One of the key considerations when designing a PLL demodulator system is the loop filter, that is a low pass filter (LPF) filtering the output signal of the phase comparator (PC). The purpose of the LPF is to pass the desired relatively low-frequency portions (audio signal) of the control voltage and attenuate its high frequency components. The LPF components are connected externally as shown on Figure 3-(b) (R_6 and C_3 of pin 2) [13, 16].

The capture range and cut-off frequency of the loop filter must be determined to effectively demodulate the audio signal. The loop filter should be designed with a relatively large capture range (CR) so as to enable a fast PLL response time and anticipate variations of the FM signal. In order to achieve that, the time constant of the filter should be made sufficiently small by choosing the appropriate capacitor C_3 and resistor R_6 values.

We designed the loop filter with an indicated time constant τ of 0.01ms [13, 15]. That yields to $R_6 = 10k$ and $C_3 = 1nF$.

Considering the given formula of the datasheet [16], the capture frequency f_{cap} of the loop filter is given by (6).

$$f_{cap} = \pm\frac{1}{2\pi}\sqrt{2\pi f_L / \tau} \tag{6}$$

Here τ is the time constant of the LPF and f_L the PLL lock frequency. That lock frequency is half of the linear zone of the VCO.

$$f_{\max} - f_{\min} = 2f_L \tag{7}$$

Considering f_{offset} to be the minimum frequency and a maximum given by (5), the capture frequency can be given by (8).

$$f_{cap} = \pm 16.33kHz \tag{8}$$

The Capture Range (CR) of the loop filter can therefore be given by (9) [13, 15].

$$f_0 - f_{cap} < f < f_0 + f_{cap} \tag{9}$$

That is $65.67kHz < f < 98.33kHz$.

Cutt-off frequency

Another design parameter to be considered is the cut-off frequency of the LPF expressed by (10) [13, 15].

$$f_{cut-off} = 1/2\pi R_6 C_3 \tag{10}$$

For an optimum use of PLL linearity, the frequency lock-range should match the linear range of the VCO; also, the cut-off frequency of the LPF should match with the lock frequency of the PLL system [13].

That is:

$$f_{\max} - f_{\min} = 2f_L = 2f_{cut-off} \tag{11}$$

A numerical calculation yields:

$$f_{cut-off} = 67.00kHz$$

4. Results and Discussions

This section exposes the implementation results of the system so as to assert its validity. Considering that TX/RX modules can only transmit digital information, the use of digital PLL for the FM modulation is to format the audio signal so as to meet that requirement [11].

4.1. Characterization of the VCO

The characterization of the VCO is performed to determine the practical linear region and frequency sensitivity gain (k_{VCO}) of the VCO.

The input control voltage of VCO is varied and the corresponding output frequency is recorded. The plotted graph representing the transfer function of the VCO is presented on Figure 4. As per the graph, the linear zone is from 17.93KHz to 156KHz for a control voltage from 1V to 9V. That gives an average frequency sensitivity gain of $17.26\boldsymbol{kHz/V}$.

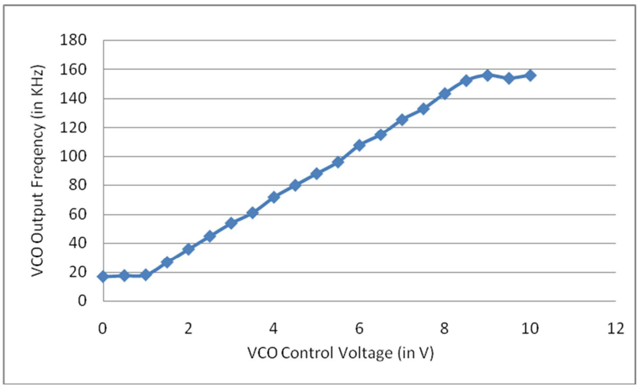

Figure 4. *VCO practical transfer characteristics.*

4.2. Prototype

Figure 5 presents two identical RF node prototypes and an illustration of their use in a single way communication; an optimum electronic mask (eventually double layer) for all in one single board and a control board will be considered for a final prototype; the experimental sensitivity radius is about 2.3m for the audio sensor and about 3m for the wake-up sensor unit.

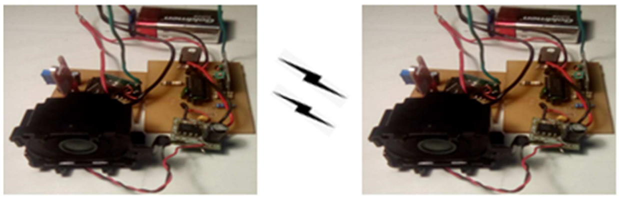

Figure 5. *Wake-up transceiver node prototypes and functioning illustration in one-way transmission.*

4.3. Coverage Range

The proposed system was tested both in indoor and outdoor environments. From the outdoor tests performed, a transmission distance of 260m was covered with a 9V battery supply. Dedicated antennas can be afforded to optimize the communication range.

4.4. Energy Consumption Measurement Results

In previous works conducted using the same RF transceiver modules, an investigation on their energy consumption was made. A simple point-to-point communication platform using two RF communication nodes was set up in order to make realistic assumptions about the energy fingerprint of the radio transmission part [17]. Random data was conveyed between the two RF modules while measuring the energy consumption of the radio front-ends. The measurements had been done by using a Keysight's DSO9064A oscilloscope and an example of such measurements is given in Figure 6[17].

Figure 6. *Emitted and received baseband waveforms [17].*

The measured instantaneous power consumption at the receiver side was 250mW and is independent on the variation of the received signal parameters. On the contrary, the power consumption at the emitter side depends on the transmitted signal's state. An average DC power consumption of about 250 mW was measured while transmitting; that average power consumption level decreased to 6μW during the standby periods [17].

5. Conclusion

This paper has provided another way of utilizing the rich Commercial Off-The-Shelf components and devices for promoting the communal living and follow up of old people in local areas of developing countries. This system can be applicable in other scenarios like security, tracking and alert, education and prevention from dissemination of an epidemic attacks.

Limitations of the system like coverage radius (300m maximum) can be made up with the use of adequately designed antenna.

Amongst particularities of this system we have aspects like no communication cost, low energy consumption and standalone or battery supply source which means cannot be cut off because of electricity shortage usually faced in developing countries. Let's highlight that the free communication aspect is fundamental in developing countries where the living conditions do not enable most of the population to have in many circumstances a communication credit to alert. Also, in developing countries, national security hardly finds sits ways because of poor or inexistent street localization.

References

[1] United Nations Organization Stabilization Mission in the Democratic Republic of the Congo, https://www.ohchr.org/Documents/Countries/CD/Report_on_Yumbi_March2019.pdf, December 16, 2018.

[2] Douglas Burton | Mounting Violence in Nigeria Tests Trump's Africa Policy, https://providencemag.com/2019/03/mounting-violence-nigeria-tests-trump-africa-policy, March 18, 2019.

[3] David McKenzie, The Ogossagou massacre is the latest sign that violence in Mali is spiraling out of control, https://edition.cnn.com/2019/03/25/africa/mali-attack-analysis-intl/index.html, March 25, 2019.

[4] Yomi Kazeem, Nigerian Christians are pawns in US right-wing media's response to the New Zealand attack, https://qz.com/africa/1576853/new-zealand-attack-right-wing-media-uses-nigeria-christian-killings/ , Quartz Africa, March 20, 2019.

[5] World Health Organization, https://www.who.int/csr/disease/ebola/faq-ebola/fr/, February 2019.

[6] L. Baiying and M. Man-Wai, "Sound-Event Partitioning and Feature Normalization for Robust Sound-Event Detection," Hong Kong Polytechnic University, Hong Kong, 2015.

[7] S. Ntalampiras, "Audio surveillance," WIT Transactions on State of the Art in Science and Engineering, vol. 54, pp. 191-205, 2012.

[8] K. M. Eyrich-Garg, 'Mobile Phone Technology: A New Paradigm for the Prevention, Treatment, and Research of the Non-sheltered "Street" Homeless, Journal of Urban Health: Bulletin of the New York Academy of Medicine, (2010) Vol. 87, No. 3.

[9] K. Ramey, "Use of Technology in Communication, https://www.useoftechnology.com/technologycommunication/amp/&ved=2ahUKEwig, September 11, 2018.

[10] M. M. Simon Haykin, An Introduction to Analog and Digital Communications, United States of America: John Wiley & Sons, Inc, 2007.

[11] Radiometrix Ltd, TX2A/RX2A Data Sheet, UHF FM data transmitter and receiver modules, http://www.radiometrix.com/, issue 1, 2nd August 2012.

[12] Texas Instruments, Datasheet on LM386 Low Voltage Audio Power Amplifier, Texas: Texas Instruments, 2017.

[13] D. K. Morgan, "Datasheet on CD4046B Phase-Locked Loop: A Versatile Building Block for Micropower Digital and Analog Applications," TEXAS INSTRUMENTS, 2003.

[14] National Conference on Computational Instrumentation, "IMPLEMENTATION OF FREQUENCY DEMODULATOR USING THE PLL DEMODULATION METHOD," CSIO Chandigarh, INDIA, 2010.

[15] A. Eman and A. Bushra, "IMPLEMENTING A FREQUENCY MODULATION (FM) MODULATOR AND DEMODULATOR," 2014.

[16] Texas Instruments, CD4046B Phase-Locked Loop: A Versatile Building Block for Micropower Digital and Analog Applications, Application Report SCHA002A - February 2003.

[17] P. Tsafack et al, "Effective Consumption and Equity Distribution of Community Water in Developing Countries: A Case Study", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, (Under review).