A MICROWAVE RADIO FOR DOPPLER RADAR SENSING OF VITAL SIGNS

Amy Droitcour, Victor Lubecke*, Jenshan Lin*, Olga Boric-Lubecke*

Department of Electrical Engineering, Stanford University, Stanford, California, USA 94305

*Bell Laboratories, Lucent Technologies, Murray Hill, New Jersey, USA 07974

Abstract — **A microwave radio for Doppler radar sensing of vital signs is described. This radio was developed using custom DCS1800/PCS1900 base station RFICs. It transmits a single tone signal, demodulates the reflected signal, and outputs a baseband signal. If the object that reflects the signal has periodic motion, the magnitude of the baseband output signal is directly proportional to the periodic displacement of the object. When the signal is reflected off a person's chest, this radio with appropriate baseband filters can detect heart and respiration rates from a distance as large as one meter from the target.**

I. Introduction

An estimated one hundred million Americans suffer from chronic health conditions including heart disease, lung disorders, and diabetes, and treatment for these conditions accounts for three-fourths of total US healthcare costs [1]. Consequently, there is a growing market for appliances that allow remote monitoring of health parameters and transfer of the recorded data to a physician, for convenience and cost reduction. Non-invasive sensing of circulatory and respiratory movements with a microwave Doppler radar [2] could be applied to such remote monitoring. Using telecommunications devices and frequencies for this remote sensing will facilitate the use of existing telecommunications networks to transfer patient data to health professionals [3].

Microwave Doppler radar monitoring of respiratory [4], cardiac [5] and arterial [6] movements was demonstrated with commercially available waveguide X-band Doppler transceivers in the late 1970's. A number of similar custom transceivers were developed in the mid-1980's, including a life detection system [7] and a superficial temporal artery monitor for military pilots [8]. All of these systems used the bulky and comparatively expensive radio components that were available at the time. Owing to the recent rapid expansion of wireless communications and information technology, inexpensive integrated radio circuits are readily available today. Smaller, lighter, and less expensive circuitry will diversify the feasible applications of this technology. In this paper, a compact prototype Doppler radar, using 0.25 μm silicon BiCMOS RFICs developed for DCS1800/PCS1900 base station applications, is described. Respiration and heart activity were successfully detected using this radio from distances up to one meter from the target.

II. Doppler Radio Architecture

According to Doppler theory, a constant frequency signal reflected off an object with a periodically varying displacement will result in a reflected signal at the same frequency, but with a time varying phase, $\phi(t)$. Analogous to the phase shift on a transmission line terminated with a load at a varying position, this time varying phase is proportional to the displacement, $x(t)$:

$$\phi(t) = \frac{4\pi}{\lambda} x(t), \qquad (1)$$

where λ is the wavelength of the signal. The reflected signal is effectively phase modulated (PM). If the change in displacement is small compared to the wavelength of the signal, the phase change will be small, and the PM signal can be directly demodulated by mixing it with a portion of the original signal. The demodulated signal is then proportional to the periodic displacement of the reflecting object (Eq. (1)). If this object is a person's chest, the demodulated voltage waveform represents displacement due to respiration and heart activity. A microwave radio based on this principle was developed for such measurements.

A block diagram and photograph of the Doppler radio are shown in Fig. 1(a) and (b), respectively. A voltage-controlled oscillator (VCO) is used to generate a constant frequency local oscillator (LO) signal. An active balun amplifier splits the signal into the RF output signal that drives the antenna and the reference LO signal that is used for demodulation. Another active balun amplifier transforms this single-ended LO signal into a differential signal, which is required for the double balanced mixer. A

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