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A DESIGN OF HIGH FREQUENCY SUBSTRATE INTEGRATED WAVEGUIDE BASED LEAKY WAVE ANTENNA FOR NON-INVASIVE RESPIRATION MONITORING

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Abstract

For the patients in intensive care unit, monitoring of cardiorespiratory activity is very crucial. For new born babies or the patients who were given sedatives, the monitoring of respiratory activity is very important failure of monitoring can be life taking. Current methods of respiration monitoring involve direct contact of electrodes with the patient which can be taken off by patient unintentionally. However with the use of High frequency EM waves, the contactless method can be used to monitor these respiratory activities. The study has been carried out for non-invasive techniques and an antenna design is proposed for the monitoring of respiratory motion. The antenna has advantage of compact size, narrow radiation width and inexpensive design. In the modeled antenna PCB is taken as dielectric and is analyzed for 8 GHz frequency, the electric field intensity of antenna is 69.4 and has far field narrow radiation pattern with gain of 1 dB.

1. Introduction

Vital sign monitoring is very important factor when a patient is suffering from apeona, or is in intensive care unit (ICU). Under normal condition, a normal adult person has respiratory rate of 12-15 breaths/minute [1]. Due to any anesthesia given to any patient, the respiratory activity may go low which can be life taking. So, proper monitoring of respiratory activity is crucial for patients even for new born babies. The existing methods are

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contact based methods which involve some sort of electrodes to be placed on body. But it is difficult to put/tie electrodes on burned patient or new born babies [2]. Even for normal patient, the electrodes can be taken of unintentionally. The non-invasive methods involve contactless respiration monitoring in which an antenna with high frequency can monitor the periodic respiratory activity. The antenna should be compact and should have narrow radiation beam so that it should not interfere any other device. Substrate Integrated Waveguide (SIW) has a planar structure and the two metallic rows are used to contrive the structure. These metallic rows are linked with upper and lower metallic ground material used is the dielectric substrate. This as a whole acts as High Pass Filter. SIW has an advantage of low profile as compared to the traditional waveguide cavity. Other advantages include easy integration of SIW with microstrip, fabrication tolerance is much smaller and low profile as compared to waveguide cavity [3-4]. SIW has also some advantages over microstrip resonators which include easy integration of SIW with the heat sink, self-packaging and the radiation loss is very less for mm waves [5]. SIW resonators have its own benefits including compact size and low cost of production.

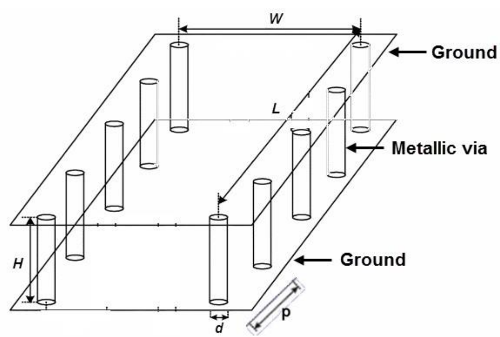

Figure 1. Structure of Substrate Integrated Waveguide.

2. Principle of Respiration Monitoring

Using microwave signals, detection of activity of heart and respiration can be determined effectively even in non-invasive manner. The microwaves have ability to penetrate through heavy clothing which enables a patient to wear clothes all the time. This is the advantage over laser based method for respiration monitoring. Another advantage of electromagnetic wave is it can detect respiration activity over large area of body while other contact less methods like ultrasonic method and infrared method has to be concentrated on chest and nose respectively.

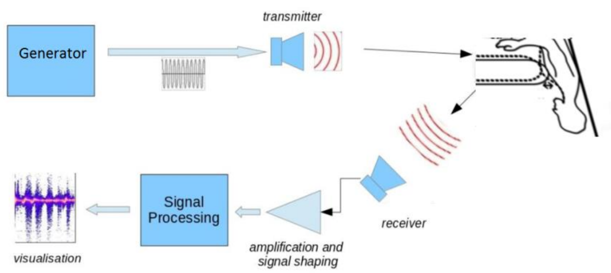

Figure 2. Basic principle of non-invasive respiration monitoring using EM waves.

When any electromagnetic signal is exposed on a continuously moving object, the reflected signal undergoes phase shift. Figure 2 shows the non-invasive circuitry and patient under respiration monitoring [2]. If the body is having periodic motion, the phase shift produced is analogues to phase shift due to varying termination location on transmission line. Hence the signal reflected from the body of patient has information about respiratory activity and can be easily extracted using inexpensive circuitry.

3. Design parameter of Substrate Integrated Waveguide and Leaky Wave Antenna

A. Design Parameter

Firstly, the formation of Vertical Perfect conductor walls is made inside the dielectric substrate with metallic Vias. No tuning is required to combine this conductor wall with the other elements present in the system of the platform having single substrate [6]. The length of the cavity is given by L, width by W and the height is given by H. d is denoted as the diameter of the vias and p by the vias spacing. The spacing in between the vias should not be more than half the guided wavelength in the high frequency equation. In this only the TE mode is considered and is dominant. There is no existence of TM mode. This is because of vias at the sidewalls [3]. Cut off frequency can be equated as [7]

$$fc = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \tag{1}$$

B. Conductor Losses

In Conductor losses are given by

$$\alpha_c = R_c \frac{(2h\pi^2 + l^2k^2)}{l^3 h\beta k\eta} \tag{2}$$

k-free space wave number β represents phase constant η is medium's intrinsic impedance and is given by

$$\eta = \sqrt{\frac{\mu_0}{\varepsilon_0 \varepsilon_\tau}}. \tag{3}$$

Conductivity of material is given by σ R_s is surface resistivity of the conductors

$$R_s = \sqrt{\frac{\omega\mu_0}{2\sigma}} \tag{4}$$

$$\alpha_{wav} = \alpha_d + \alpha_c. \tag{5}$$

C. Radiation Loss

Radiation losses are due to gaps between metal vias. These are mostly negligible however if gap is large between the vias, the losses can be more. It is given by [8]

$$\alpha_R = \frac{\frac{1}{w}\left(\frac{d}{w}\right)^{2.84}\left(\frac{s}{d} - 1\right)^{6.28}}{4.85\sqrt{\left(\frac{2w}{\lambda}\right)^2 - 1}}. \tag{6}$$

These losses are measured in dB/m.

D. Quality Factor

The unloaded quality factor of the waveguide which includes three types of losses is given by equation [6]

$$Q_u = \frac{Q_c \cdot Q_d \cdot Q_r}{Q_c \cdot Q_d + Q_d \cdot Q_r + Q_r \cdot Q_c}, \tag{7}$$

where Q_c is the conductor losses by upper and lower ground plane, Q_d is the dielectric loss conveyed by dielectric substrate and Q_r is the radiation losses between the adjacent vias [9].

Conversely as discussed, the radiation losses can be controlled by spacing the via distance p smaller than half guided wavelength of highest operation frequency.

3. Proposed Antenna Design

Figure 3 demonstrates the design of model [10]. Using the design equations for frequency 8 GHz, the dimensions of substrate is of 60 mil width and is matched with 50Ω input and output line by taper. The calculated and modeled width of antenna is 21 mm and calculated height is 1.52mm. 6-C shaped slots are made on top surface for leaky modes (radiation). Modeled antenna is put in 65 mm radial spherical air domain.

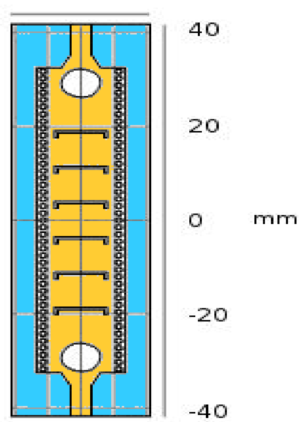

Figure 3. Designed antenna.

The meshing was done by tetrahedral mesh with five elements per wavelength. The figure 4 shows the meshing of structure.

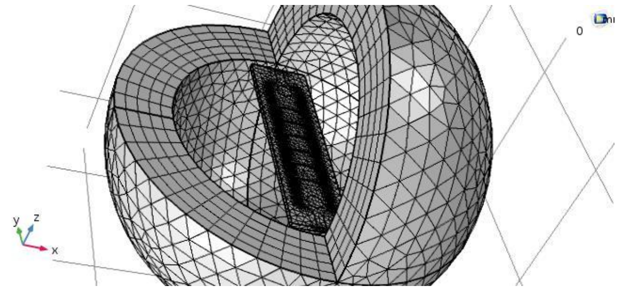

Figure 4. Meshing of design.

4. Result and Discussion

The design is simulated on 4x2.60 GHz processor speed for frequency 8 GHz. PCB material is taken as dielectric which has relative permittivity equals to 3.38 and relative permeability is taken as 1. The maximum field intensity for 8 GHz is 69.4V/m which is shown in figure 5. By observing this figure it can be seen that the input wave (from lumped port) is distributed well all in the modeled structure.

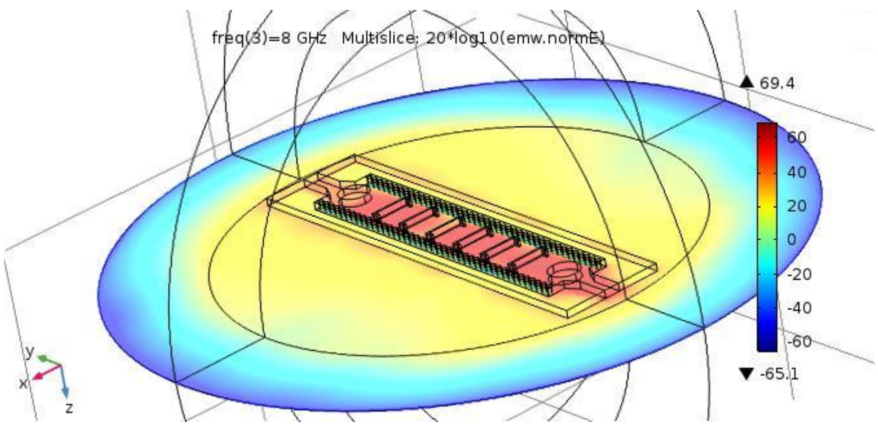

Figure 5. Electric field intensity plot for 8 GHz.

The radiation plot is shown in figure 6. From the radiation plot it can be seen that the radiation pattern has far field gain of 1dB. The gain is unidirectional as needed for the respiration monitoring antenna. The radiation pattern is narrow and has very less other side and back lobes so it will not interfere in other EM based devices.

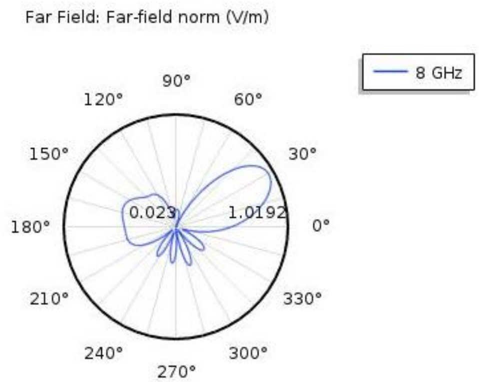

Figure 6. 2D far field radiation pattern.

5. Conclusion

While the patient is under monitoring, it is difficult to forecast the failure of respiratory activity. A continuous and contactless monitoring of respiration motion is very crucial for patient with apeona, or given any anesthesia or new born babies. Modeling and simulated experiment work was carried out to analyze and investigate SIW based Leaky Wave Antenna structure for frequency 8GHz. The Electric field intensity and radiation far filed plot were calculated for given frequency range. Proposed waveguide antenna is compact in size and has narrow radiation pattern and can be used for antenna source in monitoring respiratory activity.

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