system is superior to ROF system, which leads to large power-loss and the restriction of the transmission distance by transmitting the MMW signals over optical fiber. The MMW signals take a reasonable frequency-band, which are readily controllable. The proposed technology would be contributed to the future optical, wireless, and ubiquitous communications.

ACKNOWLEDGMENTS

This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD) (KRF-2005-041-D00548).

REFERENCES

1. M.F. Iskander and Y. Zhengging, Propagation prediction models for wireless communication systems, IEEE Trans Microwave Theory Tech 50 (2002), 662–673.
2. R. Berezdivin, R. Breinig, and R.T. Raytheon, Next-generation wireless communications concepts and technologies, IEEE Commun Mag (2002), 108–116.
3. L.L. Yang and L. Hanzo, A multiple access scheme for ubiquitous broadband wireless communications, IEEE Commun Mag (2003), 116–124.
4. D. Rohde, H. Ehlers, R. Ziegler, R.-P. Braun, J. Braunstein, W. Bronner, and G. Grosskkopf, Optic/millimeter waves converter for 60 GHz radio-over-fiber systems, In: Proceedings of the 9th Microwave Optronics Conference, Sindelfingen, Germany, 1997, pp. 311–315.
5. J. Yu, Z. Jia, L. Yi, Y. Su, G.K. Chang, and T. Wang, Optical millimeter-wave generation or up-conversion using external modulators, IEEE J Lightwave Technol 18 (2006), 265–267.
6. C. Lim, A. Nirmalathas, M. Attygalle, D. Novak, and R. Waterhouse, On the merging of millimeter-wave fiber-radio backbone with 25-GHz WDM ring networks, IEEE J Lightwave Technol 21 (2003), 2203–2210.
7. K.H. Park, A continuous-wave millimeter wave generated from optical signals by applying optical technology for optical-to-radio systems, Microwave Opt Technol Lett 47 (2005), 122–123.
8. D. Wake, C.R. Lima, and P.A. Davies, Optical generation of millimeter waves signals for fiber-radio systems using a dual-mode DFB semiconductor laser, IEEE Trans Microwave Theory Tech 43 (1995), 2270–2276.
9. A. Hsu, S.L. Chuang, and T. Tanbun-Ek, Tunable dual-mode operation in a chirped grating distributed-feedback laser, IEEE Photon Technol Lett 12 (2000), 963–965.
10. A. Yariv, Introduction to optical electronics, Holt, Rinehart, and Winston, New York, 1971.

HUMAN PERICARDIAL FLUID AT MICROWAVE FREQUENCIES

Anil Lonappan,[1] Benzy Paul,[2] V. O. Thimothy,[3] C. Rajasekaran,[4] Vinu Thomas,[1] Joe Jacob,[1] and K. T. Mathew[1]

[1] Department of Electronics, Microwave Tomography and Materials Research Laboratory, Cochin University of Science and Technology, Kochi-682 022, India; Corresponding author: anil@cusat.ac.in
[2] Department of Pathology, Mahatma Gandhi Mission's Medical College, Kamothe, Navi Mumbai 410 209, India
[3] Department of Surgery, Amala Institute of Medical Sciences and Research Centre, Amala Nagar, Thrissur 680 555, India
[4] Department of Medicine, Medical College, Trivandrum 695 011, India

Received 13 May 2008

ABSTRACT: *This article reports a new method of analyzing pericardial fluid based on the measurement of the dielectric properties at microwave frequencies. The microwave measurements were performed by rectangular cavity perturbation method in the S-band of microwave frequency with the pericardial fluid from healthy persons as well as from patients suffering from pericardial effusion. It is observed that a remarkable change in the dielectric properties of patient samples with the normal healthy samples and these measurements were in good agreement with clinical analysis. This measurement technique and the method of extraction of pericardial fluid are simple. These results give light to an alternative in-vitro method of diagnosing onset pericardial effusion abnormalities using microwaves without surgical procedure.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 155–158, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24010

Key words: *pericardial fluid; pericardial effusion; cavity perturbation; clinical analysis*

1. INTRODUCTION

The survival rate is increased in heart patients based on the earlier detection of heart abnormalities or rhythm. Numerous diagnostic techniques are available for detecting heart abnormalities and most of the techniques are either invasive or noninvasive and most of them are time consuming procedures. These concerns augment the search for new techniques that can find other physical tissue properties at the onset of heart abnormalities.

Pericardial fluid is secreted by the serous membrane on the pericardious sac on the outside of the heart. The pericardial cavity contains between 15 and 50 ml of pericardial fluid. It is similar to the serous fluid that is found in the brain for cushioning and ability to move semi-freely. A pericardial effusion is the presence of excessive pericardial fluid and is an abnormal accumulation of fluid in the pericardial cavity. Because of the limited amount of space in the pericardial cavity, fluid accumulation will lead to an increased intrapericardial pressure and this can negatively affect heart function. When there is a pericardial effusion with enough pressure to adversely affect heart function, this is called cardiac tamponade. Pericardial effusion usually results from a disturbed equilibrium between the production and reabsorption of pericardial fluid, or from a structural abnormality that allows fluid to enter the pericardial cavity. Although small effusions occur in many clinical scenarios and are not necessarily dangerous, large and rapidly accumulating effusions may cause cardiac tamponade, a life-threatening complication. Ben-Horin et al. studied the composition of pericardial fluid in patients undergoing open heart surgery [1]. Diagnosing the onset pericardial effusion abnormalities are crucial to increase the survival rate, and the present study reports a new method of detecting the onset of pericardial effusion based on the measurement of the dielectric properties of pericardial fluid using cavity perturbation technique in the S-band of microwave frequencies.

Biological effects of microwave and the application of microwaves in medicine are the developing areas of research. The increasing use of microwave technology is prevalent in various applications in diagnostic and therapeutic medicine [2]. The nonionizing microwave radiation interacts with tissues and obtains a large dielectric contrast according to their water content. Thus, there is a need to study the interaction of microwave with tissues especially its effect on biological materials. The key element in the microwave study is the determination of the absorbed energy. The amount of energy absorbed is a function of the complex permittivity of a material [3]. Hence, it is crucial to know the dielectric properties of biological materials and the various constituents thereof. Exhaustive studies of dielectric parameters of various human tissues and body fluids at different RF frequencies have been reported [4–6]. Different measurement techniques can be adopted to measure the complex permittivity of a material and the chosen technique depends on various factors such as the nature of the sample and the frequency range used [7–10]. When only very small volumes of the sample are available, the cavity perturbation technique is an attractive option as it requires only minute volumes for the measurement [11]. This makes it suitable for the dielectric study of pericardial fluid, as only very small volumes can be only be extracted by procedure. However, no data is available for the complex permittivity of pericardial fluid in the literature. The rectangular cavity perturbation technique has been employed for the measurement of the dielectric parameters of pericardial fluid samples obtained from healthy persons as well as from patients with pericardial effusion in this work, in the frequency range of 2–3 GHz. It is noticed that a remarkable change in the dielectric properties of effusion samples with the normal healthy samples and these measurements were in good agreement with clinical analysis. This microwave measurement procedure is simple and extraction of pericardial fluid from persons is least painful and nonsurgical in nature. These results prove an alternative in-vitro method of detecting the onset of pericardial effusion based on the measurement of the dielectric properties of pericardial fluid using microwaves without surgical procedure.

2. SAMPLE PREPARATION

The skin of the chest will be cleaned with antibacterial soap and a small needle is inserted into the chest between the ribs into the pericardium, which is the thin sac that surrounds the heart, and a small amount of fluid is withdrawn. Then the samples were filled in the sample holder and kept at 1°C. Measurements were carried out on samples which were less than 1-day-old.

3. MATERIALS AND METHODS

The experimental set-up consists of a transmission type S-band rectangular cavity resonator, HP 8714 ET network analyzer. The cavity resonator is a transmission line with one or both ends closed. The numbers of resonant frequencies are determined by the length of the resonator. The resonator in this set-up is excited in the TE_{10p} mode. The sample holder which is made of glass in the form of a capillary tube flared to a disk shaped bulb at the bottom is placed into the cavity through the nonradiating cavity slot, at broader side of the cavity which can facilitate the easy movement of the holder. The resonant frequency f_o and the corresponding quality factor Q_o of the cavity at each resonant peak with the empty sample holder placed at the maximum electric field are noted. The same holder filled with known amount of sample under study is again introduced into the cavity resonator through the nonradiating slot. The resonant frequencies of the sample loaded cavity are selected and the position of the sample is adjusted for maximum perturbation (i.e. maximum shift of resonant frequency with minimum amplitude for the peak). The new resonant fre-

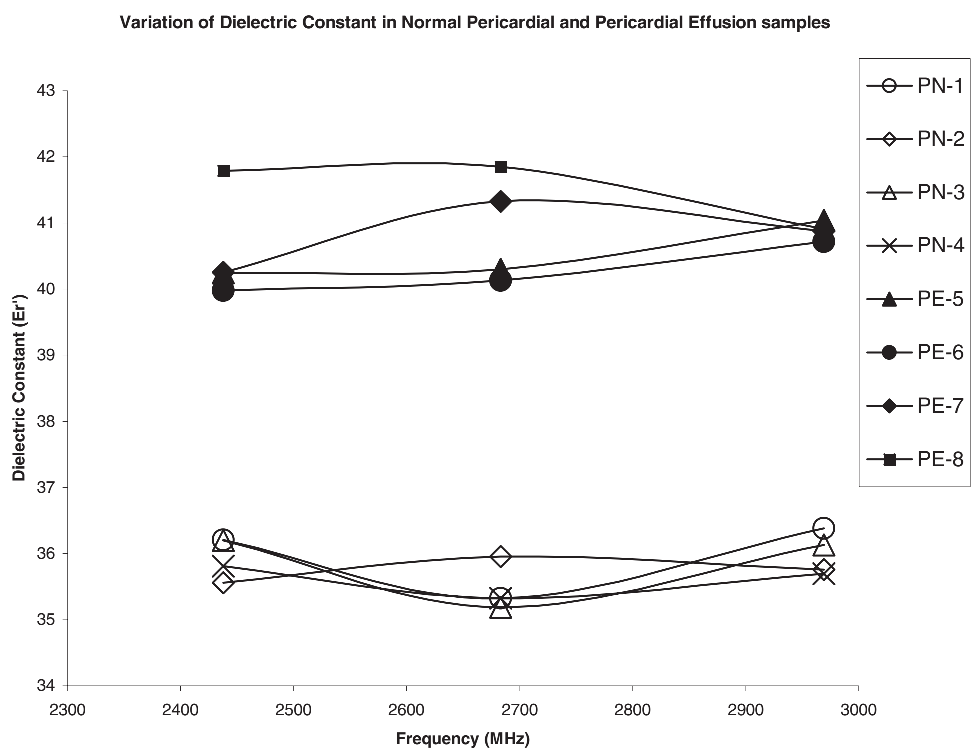

Figure 1 Variation of dielectric constant in normal pericardial sample and pericardial effusion samples

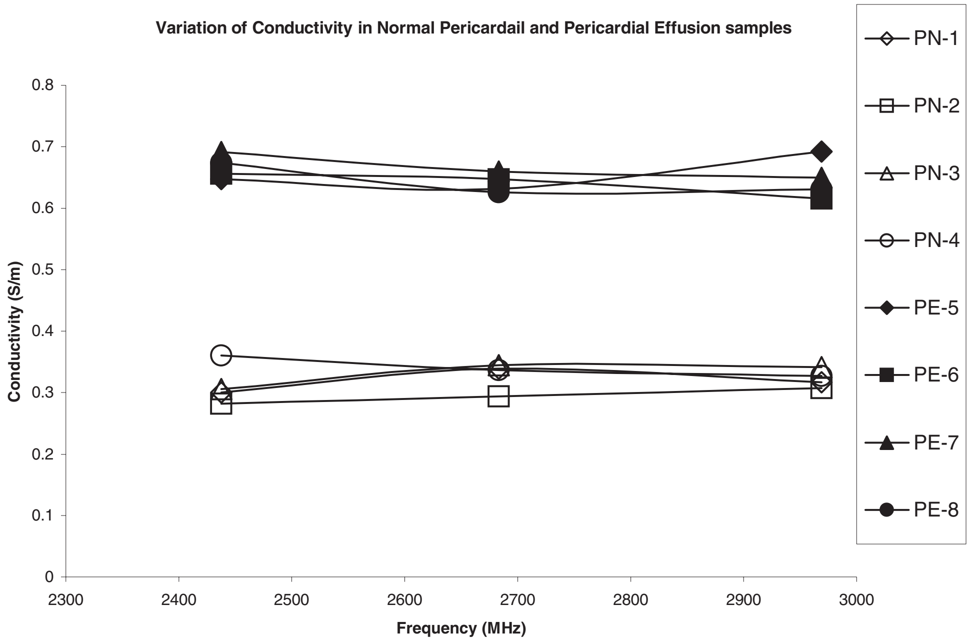

Figure 2 Variation of conductivities in normal pericardial sample and pericardial effusion samples

quency f_s and the quality factor Q_s are noted. The same procedure is repeated for other resonant frequencies.

4. THEORY

When a material is introduced into a resonant cavity, the cavity field distribution and resonant frequency are changed which depend on shape, electromagnetic properties, and its position in the fields of the cavity. Dielectric material interacts only with electric field in the cavity

According to the theory of cavity perturbation, the complex frequency shift is related as [11]

$$-\frac{d\Omega}{\Omega} \approx \frac{(\bar{\varepsilon}_r - 1)\int_{V_s} E \cdot E_0^* dV}{2\int_{V_c} |_0|^2 dV} \quad (1)$$

$$\text{But } \frac{d\Omega}{\Omega} \approx \frac{d\omega}{\omega} + \frac{j}{2}\left[\frac{1}{Q_s} - \frac{1}{Q_0}\right] \quad (2)$$

Equating (1) and (2) and separating real and imaginary parts results

$$\varepsilon_r' - 1 = \frac{f_o - f_s}{2f_s}\left(\frac{V_c}{V_s}\right) \quad (3)$$

$$\varepsilon_r'' = \frac{V_c}{4V_s}\left(\frac{Q_o - Q_s}{Q_o Q_s}\right) \quad (4)$$

Here, $\varepsilon_r = \varepsilon_r' - j\varepsilon_r''$,$\varepsilon_r$ is the relative complex permittivity of the sample, ε_r' is the real part of the relative complex permittivity, which is known as dielectric constant. ε_r'' is the imaginary part of the relative complex permittivity associated with the dielectric loss of the material. V_s and V_c are corresponding volumes of the sample and the cavity resonator. The conductivity can be related to the imaginary part of the complex dielectric constant as

$$\sigma_e = \omega\varepsilon'' = 2\pi f \varepsilon_0 \varepsilon_r'' \quad (5)$$

5. RESULTS AND DISCUSSION

The microwave studies of pericardial fluid samples were done using cavity perturbation technique collected from healthy donors

TABLE 1 Variation of Constituents in Pericardial Fluid Samples

Sample	Color	Lactate Dehydrogenase (10^3/mm^3)	Lymphocytes (10^3/mm^3)	Monocytes (10^3/mm^3)	Proteins (g/dl) Albumin	Proteins (g/dl) Globulin
PN-1	Clear	2.2	0.5	1.4	3.5	3.4
PN-2	Clear	1.9	0.4	1.2	4.2	2.9
PN-3	Cloudy	2.6	0.6	1.5	3.8	3.1
PN-4	Clear	2.1	0.5	1.3	4.9	2.3
PE-5	Bloody	2.0	1.1	3.3	10.7	12.5
PE-6	Cloudy	2.3	0.9	3.8	14.6	11.9
PE-7	Cloudy	2.4	1.0	3.7	12.4	15.7
PE-8	Clear	1.9	1.2	3.4	17.3	13.8

as well as from the patients and the results are shown in Figures 1 and 2. These results are novel using microwave techniques for the case of pericardial fluid. Clinical evaluation of the pericardial fluid samples is also done and the results are tabulated in Table 1. They found it was relatively rich in lactate dehydrogenase, low in protein, and high in lymphocytes and monocytes. From Figure 1, it is noticed that the effusion samples exhibit a higher dielectric constant than that of the normal samples. In Figure 2, the variation of conductivity of normal and effusion samples are plotted. It can be found that distinct variation in the conductivities of normal samples and the effusion samples. The increase in conductivity in effusion samples is due to the presence of higher level of protein contents such as albumin and globulin than the normal pericardial samples. Thus in the specified band of frequencies, normal pericardial and pericardial effusion samples were studied and exhibit distinct variation of dielectric constant and conductivity with frequency.

6. CONCLUSION

The microwave characterization of the pericardial samples is done using cavity perturbation technique. The cavity perturbation technique is quick, simple, and accurate and it requires very low volume of sample for measuring the dielectric properties of tissue samples like pericardial samples. It is observed that a remarkable change in the dielectric properties of pericardial effusion samples with the normal healthy samples and these measurements were in good agreement with clinical analysis. This measurement technique is simple and the extraction of pericardial fluid from persons is least painful and nonsurgical in nature. These results prove an alternative in-vitro method of diagnosing onset pericardial effusion abnormalities using microwaves without surgical procedure.

REFERENCES

1. S. Ben Horin, A. Shinfeld, E. Kachel, A. Chetrit, and A. Livneh, The composition of normal pericardial fluid and its implications for diagnosing pericardial effusions, Am J Med 118 (2005), 636–640.
2. Special issues, IEEE Trans Microwave Theory Tech 50 (2002).
3. A. Von Hippel, Dielectric and waves, Artech House, Norwood, MA, 1995.
4. S. Gabriel, R.W. Lau, and C. Gabriel, The dielectric properties of biological tissues. II. Measurements on the frequency range 10Hz to 20GHz"Literature survey, Phys Med Biol 41 (1996), 2251–2269.
5. H.F. Cook, Dielectric behavior of human blood at microwave frequencies, Nature 168 (1951), 247–248.
6. H.F. Cook, The dielectric behavior of some types of human tissues at microwave frequencies, Br J Appl Phys 2 (1951), 295–300.
7. D.K. Ghodgaonkar, V.V. Varadan, and V.K. Varadan, Free space measurement of complex permittivity and complex permeability of magnetic materials at microwave frequencies, IEEE Trans Instrum Measurement 19 (1990), 387–394.
8. D.K. Ghodgaonkar, V.V. Varadan, and V.K. Varadan, A free space method for measurement of dielectric constant and loss tangents at microwave frequencies, IEEE Trans Instrum Measurement 38 (1989), 789–793.
9. W. Barry, A broadband, automated, stripline technique for the simultaneous measurement of complex permittivity and complex permeability, IEEE Trans Microwave Theory Tech 34 (1986), 80–84.
10. Z. Abbas, R.D. Pollard, and R.W. Kelsall, A rectangular dielectric waveguide technique for determination of permittivity of materials at W-band, IEEE Trans Microwave Theory Tech 46 (1998), 2011–2015.
11. K.T. Mathew, Encyclopedia of RF and microwave engineering, Vol. 4, Wiley-Interscience, USA, 2005, pp. 3725–3735.

A COMPACT QUASI-ELLIPTIC BANDPASS FILTER USING COUPLED DUAL QUASI-LUMPED LC RESONATORS

Lin Li, Zheng-Fan Li, and Qi-fu Wei
Department of Electronic Engineering, Shanghai Jiao Tong University, No. 800 Dongchuan Road, Shanghai 200240, China; Corresponding author: lilin_door@hotmail.com

Received 14 May 2008

ABSTRACT: *This letter proposes a compact microstrip bandpass filter using coupled dual quasi-lumped LC resonators. With the proposed topology, two transmission zeros are generated at both low and high stopband near the passband to create quasi-elliptic response. A filter sample is designed and fabricated to provide an experimental verification.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 158–160, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24009

Key words: *bandpass filter; quasi-lumped LC resonator; transmission zero; quasi-elliptic response; even and odd mode analysis*

1. INTRODUCTION

Bandpass filters [1] of high quality and compact size are always desirable in model wireless communication system with operating functions of in-band transmission and out-of-band rejection. The performance of bandpass filter can benefit a lot from transmission zero point technique. Generating transmission zero points and properly locating them at either side of the passband can develop sharp and deep rejection outside the passband without sacrificing the performance of the passband. Thus, a low-order BPF with the help of extra transmission zero points can meet the stopband requirements that are usually achieved by high-order filters. To achieve better selectivity, many improvements on creating suitable transmission zeros were reported recently [2, 3]. The cross-coupled configuration is widely used to create transmission zeros, and thus the filter exhibits elliptic function response [4, 5]. And source-load coupling is also well known to be capable of producing near passband transmission zeros [6, 7].

In this letter, we present a novel topology of two-pole microwave BPFs consisting of only dual quasi-lumped LC resonator as shown in Figure 1. Employing quasi-lumped resonator can contribute a lot to size reduction. Further, it will be demonstrated using even and odd mode analysis that two transmission zeros can be generated at both low and high stopbands to create a quasi-elliptic response, which enhances the filter's performance remarkably.

2. THEORY

The proposed resonator in Figure 1 is a quasi-lumped LC resonator including an interdigital capacitance. The larger patch at its bottom is also a capacitor to compose the resonator and connect to the I/O port. When two resonators are put side by side as seen in Figure 1, they will couple to one another. Figure 2(a) has given the distributed equivalent circuit. Because this topology is symmetric, the method of even and odd mode analysis can be applied. The equivalent even and odd mode circuits are given in Figures 2(b) and 2(c), obtained from the replacement of the reference plane with the magnetic and electric walls, respectively.

Network theory [2] relates the transmission coefficient of the filter to the odd and even mode input admittances by the following formula: