A HYBRID RECTANGULAR DIELECTRIC RESONATOR ANTENNA WITH SLOT FOR WBAN APPLICATIONS

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Abstract—Hybrid double frequency antennas are in huge requirement because of fast advancement of the recent wireless communications towards the body area networks applications. Therefore in this paper, a compact hybrid dielectric resonator antenna with a slot sustained by a microstrip line that is feasible for wireless body area network is investigated. In this model, the dielectric resonator performs the functions of an effective radiator along with the feeding structure and the slot in the ground plane. By varying the structural parameters, the antenna is built to oscillate at two different frequencies; one is from the dielectric resonator antenna (DRA) and the other from the slot. The structure has a dielectric resonator with the resonant frequency of 2.4 GHz (Industrial, Scientific and Medical) and a parasitic slot with a resonant frequency of 403 MHz (Medical Implantable Communication Service). The physical and geometrical parameters of these resonators are resonating to attain the required performance parameters. In order to the performance of the investigated antenna, functional parameters such as return loss, bandwidth, voltage standing wave ratio (VSWR), and radiation pattern are intended by the simulation of the structure with high frequency structure simulator (HFSS).

Keywords—Ceramic dielectric material; dielectric resonator antenna (DRA); dual band operation; microstrip feed line; WBAN.

I. INTRODUCTION

A dielectric resonator (DR), as evident from the name itself, is a resonant structure. Hence a DR antenna (DRA) can be expected to have a more bandwidth. The different types DRAs such as cylindrical, rectangular, and hemispherical shapes [2]-[10] have been presented in literature. Cylindrical and rectangular dielectric resonator antennas are having attractive features over the triangular and hemispherical shapes.

The double band hybrid structure [2] to procure dual frequency operation for WBAN applications is proposed. The proposed model can be treated as the combination of DRA and other radiating resonator, such as a slot resonator [3]. These two elements are tightly coupled together and resonate at two different frequencies. Their radiation patterns have different performance for WBAN applications.

The benefit of dielectric resonators [4] in feeding systems requires accurate knowledge to stackle the resonators and components. However, the resonant feeding structure adopted in these reported designs, such as microstrip-fed aperture-coupled, co-axial probe coupling, co-planar slot feed and CPW-fed slot arrangement offers more flexibility and is directly compatible with different mounting surfaces. In this model, in order to avoid via holes, the microstrip feed line is suggested [6]. The microstrip line [11] placed on the same substrate excites a dielectric resonator (DR) that could be placed directly over the feed line. The advantage of microstrip feed is easy to fabricate, simple to match by controlling the inset feed position, low spurious radiation and easy to model.

To represent the method, the suggested hybrid dual-band antenna [7] is designed for wireless body area networks. It consists of upper (2.4 GHz) and lower (403 MHz) frequencies of the dual-band antennas [8] are primarily controlled by the DRA and slot subsequently. The designed dual-band antenna has the maximum radiation directed toward the inside of the human body in the medical implantable communication service (MICS) band in order to collect vital information from the human body [9], and directed toward the outside in the industrial, scientific and medical (ISM)
band to transmit that information to a monitoring system. This model has the advantage of small size, simple structure and can achieve dual frequency operation with various radiation patterns.

The physical and geometrical parameters of these models are varying correspondingly to obtain the desired performance parameters. In this model, development of a dual band antenna to be implanted for the body which will be reasonable for both MICS range and ISM range is aimed at. This design has the advantage of simple structure, compact size, and can obtain dual band with different radiating patterns, and is very suitable for applications for wireless body area network.

II. ANTENNA CONFIGURATION

The double frequency dielectric resonator antenna with slot sustained by microstrip line is suggested. Hybrid structure is combination of two different types of resonators; it consists of rectangular dielectric resonator and slot. The suggested hybrid [12] structure, the rectangular [16] dielectric resonator antenna oscillates at 2.4 GHz (ISM) and slot [13], [15] oscillates at 403 MHz (MICS) which is suitable for wireless body area networks. These two radiating resonators are tightly coupled together and resonate at various frequencies. By varying for the radiating resonators’ position, a compact dual-band or frequency-tunable hybrid DRA can be designed. The feed line is placed on the substrate at mid point.

Figure 1 represents the side view of the suggested antenna for a WBAN. The suggested antenna has the dimensions of 40 mm × 40 mm × 11.1 mm, and a RT duroid 6010 dielectric with a relative permittivity of 10.2 is used as a substrate. It consists of a rectangular DR and a center-fed microstrip line which is printed on an RT druid 6010 substrate of thickness 1.6 mm and relative permittivity εr=10.2. The ground plane is printed on the RT duroid 6010 substrate with a dimension of 40x40 (LxW) mm². The DRA with ceramic material has a length Lr=17 mm, width Wr=18 mm and height of hr=9.5 mm, and a relative permittivity of εd=37 as shown in Figure 1. The 50-Ω feeding line has a length of Lf=30 mm and a width of Wf=3.0 mm.

The theoretical resonant frequency of the RDRA [14] is calculated by the following equation and equal to 2.4 GHz which is well suited for industrial, scientific, medical(ISM).

\[
f_0 = \frac{c}{2\pi\sqrt{\varepsilon_r}} \sqrt{k_x^2 + k_y^2 + k_z^2}
\]

\[
k_x = -\frac{\Pi}{a}, k_z = \frac{\Pi}{2b}
\]

\[
d = \frac{2}{k_y} \tan^{-1}\left(\frac{k_{y0}}{k_y}\right), k_{y0} = \sqrt{k_x^2 + k_z^2}
\]

Where, \(f_0\) = resonant frequency of the DRA, \(c\)=speed of light, \(\varepsilon_r\)=dielectric constant of the resonator, \(a\)= length of the resonator, \(d\)= width of the resonator, \(b\)= height of the resonator, \(K_x\)= coefficient in the x direction, \(K_{y0}\)=coefficient in the y direction, \(K_z\)= coefficient in the z direction.
In this letter, a new type of resonator such as slot etched in ground plane is proposed to achieve lower frequency (403 MHz) band. The structure of slot is as shown in Figure 1. It is well-known that by choosing a high permittivity substrate, a greater size reduction can be achieved. For this reason, the substrate selected for the antenna has been RT duroid 6010 ($\varepsilon_r=10.2$). The design consideration for the lower excited slot antenna is consists of five rectangular slots with different lengths and fixed width $W_S=0.2$ mm as shown in Figure 1, different rectangular slot lengths are $L_1=15$ mm, $L_2=14.8$ mm, $L_3=35.9$ mm, $L_4=20.8$ mm, $L_5=20.7$ mm.

By varying the slot dimension, the intended antenna can operate in two bands, and a good impedance match for the operating frequencies can be easily obtained. The bottom of the slot is designed to communicate with the implanted devices in the MICS band, and to reduce the human body effects of the ISM band. By adjusting the structure parameters, the DRA and slot resonates at 2.4 GHz and 403 MHz subsequently.

### III. SIMULATED RESULTS AND DISCUSSIONS

Figure 2 represents the simulated return loss of the intended hybrid DRA. The primary excited band is due to the slot while the secondary band is due to the rectangular dielectric resonator. It is observed-28 dB return loss at 0.403 GHz and -23 dB return loss at 2.4 GHz. Note that there are no frequencies to be annoyed outwardly the existence of rectangular resonator, that is, the full resonate slot mode is induced by the rectangular resonator.
Figure 2: Simulated return loss at MICS and ISM band
The radiation waves of the simulated antenna model at 403 MHz and 2.4 GHz with phi=0 (deg) and phi = 90 (degree) are represented in Figure 3. The intended antenna radiates a maximum in the broadside direction at 2.4 GHz and slot – opening resonator is radiating the waves in bidirectional at 403 MHz.
The voltage standing wave ratio (VSWR) of the intended model is as represented in Figure 4. It is given as an analysis of the mismatch between the load and the transmission line. For ideal case value of VSWR is 1 and for good impedance matching. The VSWR of investigated antenna is 1.6 at 0.403 GHz and 1.1 at 2.4 GHz.

Figure 3: Simulated radiation patterns at: (a) MICS; (b) ISM
A hybrid double frequency rectangular dielectric resonator antenna with slot opening supported by microstrip line is recommended to obtain double frequency operation. The suggested rectangular resonator and slot - space resonators are operates at the primary band (2.4 GHz) and secondary band (403 MHz) subsequently. The antenna model has been simulated and it is perceived that return loss of -28 dB, -23 dB at the resonant frequencies of 403 MHz and 2.4 GHz subsequently. The intended antenna model has small in size, less weight, reduced cost, allowable isolation and adequate operational bandwidth, with the end goal that it is reasonable for WBAN applications.

REFERENCES

[1] A. A. Kishk and Y. M. M. Antar. Dielectric resonator antennas, from J. L. Volakis: Antenna Engineering Handbook, 4th ed. USA: McGraw-Hill, Feb 2007, ch. 17.
[2] A. Khalajmehrabadi, M. K. A. Rahim and M. Khalily. Dual band double stacked dielectric resonator antenna with a p-shape parasitic strip for circular polarization, IEEE International Conference on RF and Microwave Applications, Seremban, Malasiya, pp. 444-447, Dec 2011.
[3] E. M. O’Connor and S. A. Long. The History of the Development of the Dielectric Resonator Antenna, ICEAA International Conference on Electromagnetics in Advanced Applications, Turin, Italy, pp. 872-875, Sept 2007.
[4] R. N. Simons and R. Q. Lee. Effect of parasitic dielectric resonator on CPW/aperture-coupled dielectric resonator antenna, Proc. Inst. Elect. Eng., Microw. Antennas Propag., vol. 140, pp. 336-338, Oct 1993.
[5] Hua-Ming Chen, Yang-Kai Wang, Yi-Fang Lin, Shih-Chieh Lin, and Shan-Cheng Pan. A Compact dual-band dielectric resonator antenna using a parasitic slot, IEEE Antennas and Wireless Propagation. Lett, vol. 8, pp. 173-176, April 2009.
[6] K. P. Esselle and T. S. Bird. A hybrid-resonator antenna: Experimental results, IEEE Trans. Antennas Propag., vol. 53, no. 2, pp. 870–871, Feb 2005.
[7] L. Huijema, M. Koubeissi, C. Decroze, and T. Monediere. Compact and multiband dielectric resonator antenna with reconfigurable radiation pattern, in Proc. 4th Eur. Conf. Antennas Propag., pp. 1-4, April 2010.
[8] K. W. Leung and K. K. So. Frequency-tunable designs of the linearly and circularly polarized dielectric resonator antenna using a parasitic slot, IEEE Trans. Antennas Propag., vol. 53, no. 1, pp. 572–576, Jan 2005.

[9] K. K. So and K. W. Leung. Bandwidth enhancement and frequency tuning of the dielectric resonator antenna using a parasitic slot in the ground plane, IEEE Trans. Antennas Propag. vol. 53, no. 12, pp. 4169–4172, Dec 2005.

[10] Leung K. W., K. Y. Chow, K. M. Luk and E. K. N. Yung. Low-profile Circular Disk DR antenna of very high permittivity excited by a Microstrip line, Electron. Lett. vol. 33, pp. 1004-1005, June 1997.

[11] R. A. Kranenburg and S. A. Long. Microstrip Transmission Line Excitation of Dielectric Resonator Antennas, Electron. Lett. vol. 24, pp. 1156-1157, Sept 1988.

[12] T. A. Denidni and Q. Rao. Hybrid dielectric resonator antenna with radiating slot for dual-frequency operation, IEEE Antennas Wireless Propag. Lett. vol. 3, pp. 321–323, Dec 2004.

[13] F. Elek, R. Abhari, and G. V. Eleftheriades. A uni-directional ring-slot antenna achieved by using an electromagnetic band-gap surface, IEEE Trans. Antennas Propag., vol. 53, pp. 181-190, Jan 2005.

[14] C. S. Deyoung and S. A. Long, “Wideband Cylindrical and Rectangular Dielectric Resonator Antennas C. S. Deyoung and S. A. Long, “Wideband Cylindrical and Rectangular Dielectric Resonator Antennas

[15] Zulkifli F. Y., Rodhaiah D., Rahardio E. T., Dual band microstrip antenna using U and S slot for WLAN applications, IEEE, Antenna and

[16] M. Zhang, B. Li, X. Lv, ”Cross-slot-coupled wide dual-band circularly polarized rectangular dielectric resonator antenna”, IEEE Antennas Wireless Propag. Lett., vol. 13, pp. 532-535, 2014.