Lungs Patch Structures: *Numerical Computation, Testing and Application*

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Abstract—**The constructions of the novel and robust lungs antennas were examined. Several kinds of the lungs patch structure antennas were numerically computed, fabricated and tested. A number of the lungs antenna models were designed to be suitable for large varieties of modern wireless communication applications including mobile computing devices, GPS-SAR, LTE, detection and sensing networks, satellite communications, and other cellular mobile peripherals. In this paper, each designed antenna was evaluated through a certain corresponding resonant frequency, i.e. 1.2 GHz, 1.98 GHz and ISM band 2.4-2.5 GHz. The fabrication step was performed using a simple and straightforward method that commonly applied in printing a PCB. The most advantageous of the constructed antenna lied not only on its robust and unique electrical properties but it also has a compact and reconfigurable physical structure to meet the required technical specifications.**

Keywords—Lungs patch structure, UAV, GPS-SAR, LTE, and biological inspired antenna

I. INTRODUCTION

The high availability of such rapid data transfer provided through a microwave transmission media in the modern communication networks has boosted the popularity of wireless technologies access. This may also attract more consistent innovation and intensive development of antenna systems. The antenna has in fact emerged as a vital element on the wireless networking. Most wireless applications require miniaturization or improved performance. Thus, it is required an antenna that has excellent performance, easy installation and inexpensive costs. A patch antenna structure can meet such criteria. It has several advantages such as low profile and low cost of fabrication. Due to the compactness and resistance to extreme environments (ruggedness) its use in other fields such as in aerospace and satellite applications has received much attention. The radiator layer model of the patch antenna structure is commonly in the form of rectangles, squares, circles, ellipses and triangles [1-5].

In this study, the uncommon form of the radiating element, inspired from the actual life environment [4, 6-7], were constructed and examined. The new patch structure is so-called lungs antenna. The antenna models were constructed from the conventional patch forms including four elliptical and some rectangular patches. Benefits of this antenna radiating layer includes capable of the compact construction and its easy way to be reconfigured to meet certain technical parameters such as return loss (S_{11}), patterns, impedance bandwidth, VSWR and axial ratio. In addition, its electrical properties are very sensitive to change due to the alteration of various physical parameters such as the location of the RF input port, the length (L) and the width (W) of the RF-transmission line and the effective surface area of the radiator (see Figure 1). In construction, these parameters should be set appropriately and accurately in order to obtain the optimal performance.

This paper outlines several current researches and development of lungs antenna prototype intended to be deployed in various wireless communications. There are three areas of concern where the studies are focused. These include, for instance, the GPS-SAR antenna technology onboard an autonomous spacecraft, nanosatellite antenna system for the telemetry application, and LTE technology. However, not all the constructed lungs antennas of these applications will be fully presented and discussed in this paper, but only the designed antennas intended for GPS-SAR and LTE applications that will be extensively evaluated.

II. ANTENNAS MODELING, TESTING AND EVALUATION

The radiating element of a typical lungs antenna model has been constructed through the addition and subtraction algorithms to the common patch radiating layer including some elliptical and rectangular forms during the numerical computing process using FEM-HFSS Version 13. Several models of lungs radiating element were created to meet a particular wireless application. The experimental evaluations were also performed to all antenna models. The descriptive discussions of the lungs antennas fundamental operation are presented in the following sub-sections.

As described in Figure 1, the lungs shape antenna consists of three layers, i.e. the top lungs shape conducting layer, the dielectric material, and the ground plane. The type of dielectric materials used to construct the antenna systems was the one has ε_r 4.4 (FR4-Epoxy) and the loss tangent 0.021 and the thickness h 1.6 mm. In the construction of a single lungs structure, the ground plane and the dielectric substrate size were flexibly altered to meet a certain resonant frequency. For exactly the same substrate material type and thickness, FR4-Epoxy (1.6 mm thickness) as for instance, the smaller the size of the ground plane and the dielectric layer tends to produce the higher resonant frequency. This, off course, directly relates to the intended wireless network application. However, the dimension of those lungs antenna elements will significantly increase while the array configuration is set-up. In order to design two lungs patch array from its initial single lungs patch structure the required size of the ground plane and dielectric, respectively, is almost double. The size comparison of the ground plane and dielectric substrate to configure the designed lungs array and its corresponding particular application is tabulated in Table I.

A single lungs patch antenna as depicted in Figures 1, 2 (a) and 2 (c) exploited the excellent advantages of the coaxial edge feeding technique to feed RF-power to the whole lungs alike radiating layer. As clearly visualized in the figures, a copper 50 Ω SMA connector was soldered exactly in the middle position at one edge side of a double layers PCB material. In the transmit mode, the RF-energy fed from this connector will be transported through the short transmission line of ***L*** length (see Figure 1). The wave power will be equally divided by the passive patch splitter structure [5] of ***W*** width before entering the two identical lungs conducting layers. These top conducting layers perform two functions i.e. transmitting and receiving of RF-wave. However, an opposite RF wave processing is performed as the antenna working in the receive mode.

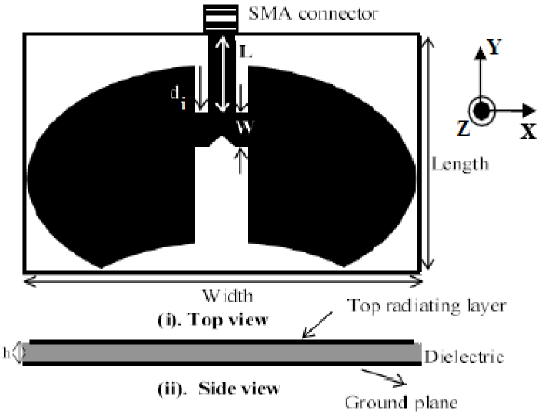

Fig. 1. Lungs shape antenna structure: (i) top view and (ii) side view

TABLE I: DIMENSION COMPARISON OF THE GROUND PLANE AND DIELECTRIC LAYER CONSTRUCTED IN AN ARRAY CONFIGURATION.

Typical Applications	Ground Plane and Dielectric Layer Size	
	Length (mm)	Width (mm)
Antenna array of 2.5 GHz nanosatellite telemetry [4]	*93.52*	*160*
Two elements array LTE 1.96 GHz	300	480
Two elements array GPS-SAR 1.2 GHz	280	495

In order to develop the antenna array for a particular application such as for the deployment in GPS-SAR, LTE and nanosatellite systems [4] an extensive optimization procedure must be performed on the constructed lungs antenna structure to meet certain technical specifications. For instance, to produce the excellent axial ratio (***AR***) 2.3 and 2.29 dB as previously tabulated in Table 2, three methods were applied on constructing the more powerful lungs patch array. First technique is by inserting a passive phase shifter [5] to a feeding line of the lungs linear array (see Figures 2 (b) and 2 (d)). The feeding port was set-up in the parallel configuration [1, 8]. Second technique adopted to achieve the required ***AR,*** the little conducting patch layer of the circle or circular form should be generated during the HFSS optimization process and used to subtract the two identical lungs patch structures. In practical, the size of the circle (or circular) patch form will determine the value of ***AR*** generated. The last technique is to optimize RF-port position along one edge side of the lungs patch structure (see Figure 2 (b)). With having those two axial ratio values it is guaranteed that the lungs antenna may work in the circular polarization property.

The electrical properties as outlined in Table II including *S_{11}, impedance bandwidth, VSWR, axial ratio (AR), beamwidth,* and *pattern* were recorded at the antenna resonant frequency for each particular application. The 3D-patterns of the single element and the two elements of the constructed lungs antennas, both for GPS-SAR and LTE applications are illustratively presented in Figure 3. Based on those figures, it is clearly shown that gain and directivity of the optimized lungs array outperformed the single lungs design.

The reflection coefficient (S_{11}) profiles of the constructed GPS-SAR and LTE-BTS antennas, both the simulated and measured S_{11}, are depicted in Figures 4 (a-b). All the measured S_{11} were recorded using VNA E5071C. From these figures, it has been shown that the constructed lungs antennas have met the required technical specifications working at certain frequency operation, i.e. 1.2 and 1.98 GHz, respectively. As tabulated in Table II, all the designed lungs antennas whether a single element or two elements array, are capable to generate the impedance bandwidth approximately 40 MHz to more than 100 MHz. While, the impedance matching are quite good where the VSWR achieved is from 1.05 to 2.

The S_{11} parameters of the designed GPS-SAR antenna are depicted in Figure 4.(a). Both the simulated and measured S_{11}, whether single lungs element or two lungs elements array, exhibited very close agreement within the intended operation frequency 1.2 GHz. The simulated single element of the lungs patch structure produces the impedance bandwidth of approximately 50 MHz while the two elements (both simulated and measured ones) exceed 100 MHz. Even though, the designed antenna is classified as the narrowband antenna (less than 8% bandwidth) however to fulfill such practical sensing, recording and transmitting the earth surface image or other environmental parameters (e.g. temperature, humidity, rain intensity and so on) from an UAV (unmanned aerial vehicle) to a ground station this available bandwidth is sufficiently enough.

The broader bandwidth of the designed lungs antennas for LTE-BTS 1.98 GHz application was obtained by configuring the single element of lungs patch structure into two elements array. The improvement of bandwidth achieved is more than 200%. The **S_{11}** profiles of the LTE-BTS antenna design is visualized in Figure 4.(b). Conceptually, the constructed antennas, both single element and array, provide the impedance bandwidth of 50 MHz and larger than 220 MHz, respectively. The bandwidth according to the measured **S_{11}** is approximately 80 MHz. However, this bandwidth will increase to more than 220 MHz while the 1.8 GHz and 2.2 GHz frequency operations are also considered.

III. CONCLUSION

Various models of lungs patch antennas have been computed, optimized, manufactured and tested to meet the particular wireless communication applications including GPS-SAR onboard an automobile aircraft, LTE BTS terminal and nanosatellite system. The designed antennas provide the good performance in terms of the electrical properties such as *pattern, gain,* S_{11} and *axial ratio* as the physical parameters of the radiating elements set-up properly to meet certain technical requirements in modern wireless networks. In average, the constructed lungs patch antennas whether it is a single element or two elements array could provide the operation bandwidth from 40 MHz to 100 MHz, approximately. The gain and directivity profiles of lungs antenna configured in the array form are better than the single elements of lungs patch structure.

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REFERENCES

[1] C. Balanis, "Antenna Theory: Analysis and Design," *3rd Edition, John Wiley &Sons Inc.*, 2005.

[2] E.Palantei, D.V.Thiel and S.G. O'Keefe,"Rectangular Patch with Parasitic Folded Dipoles: A Reconfigurable Antenna," *IEEE International Workshop on Antenna Technology (IEEE iWAT) 2008: Small Antennas and Novel Metamaterials*, Chiba, Japan, 4-6 March 2008.

[3] E. Palantei, R. M.Salehu, A. E. Putra, and A. Achmad, "Printed Microstrip Antennas (MSAs) Suitable for MS and BTS WiMAX Applications," *Proceedings of the 2nd Makassar International Conference on Electrical Engineering and Informatics (MICEEI) 2010*, Makassar Golden Hotel (MGH), Makassar, South Sulawesi, Indonesia, 27-28 October 2010, pp.42-45. On line available [14 February 2013] at http://www.unhas.ac.id/miceei/miceei2010/ProceedingsMICEEI2010_Part_One.pdf

[4] E. Palantei, S. Syarif, B. Topalaguna and Z. Ubaid, "Four Elements Array of Lungs Shape Patch Antenna for Nanosatellite Telemetry," accepted for oral presentation on *IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting,* Hilton Orlando Lake Buena Vista, Lake Buena Vista, Florida, USA July 7-12, 2013.

[5] E. Palantei, J.T. Sri Sumantyo, and K. Osa, "Rectangular Patches Array Utilized Coaxial Edge Feeding and 90^0 Phase Shifter for Achieving CP Property, " *the SANE2011-IEICE Technical Report* Vol. 111, No. 239, pp.123-126, 2011.

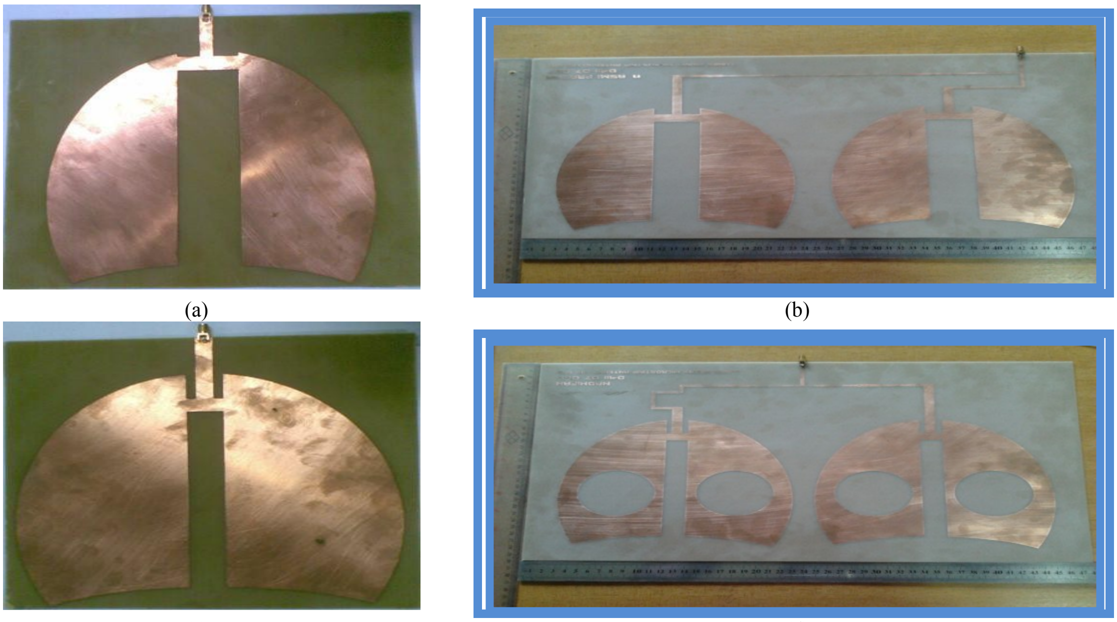
[6] Marco Briasco, Andrea F. Cattoni, Giacomo Oliveri, Marina Ottonello, Mirco Raffetto, and Carlo S. Regazzoni, "Antenna systems with embodied cognition for next generation wireless communications, " *IEEE International Symposium on* Antennas and Propagation Society, 9-15 June 2007, Honolulu, Hawaii, USA, pp.1685-1688.

[7] Noah J. Cowan, Emily J. Ma, Mark Cutkosky, and Robert J. Full, "A Biologically Inspired Passive Antenna for Steering Control of a Running Robot", *Springer Tracts in Advanced Robotics: Springer Berlin Heidelberg*, Vol.15, 2005, pp.541-550.

[8] Jorge Sosa-Pedroza, Fabiola Martínez-Zúniga and Mauro Enciso-Aguilar, "Planar Antennas For Satellite Communications," on line available [21 March 2013] at www.intechopen.com

TABLE II: ELECTRICAL PROPERTIES OF THREE DIFFERENT LUNGS PATCH ANTENNA MODELS AND THE POTENTIAL APPLICATIONS.

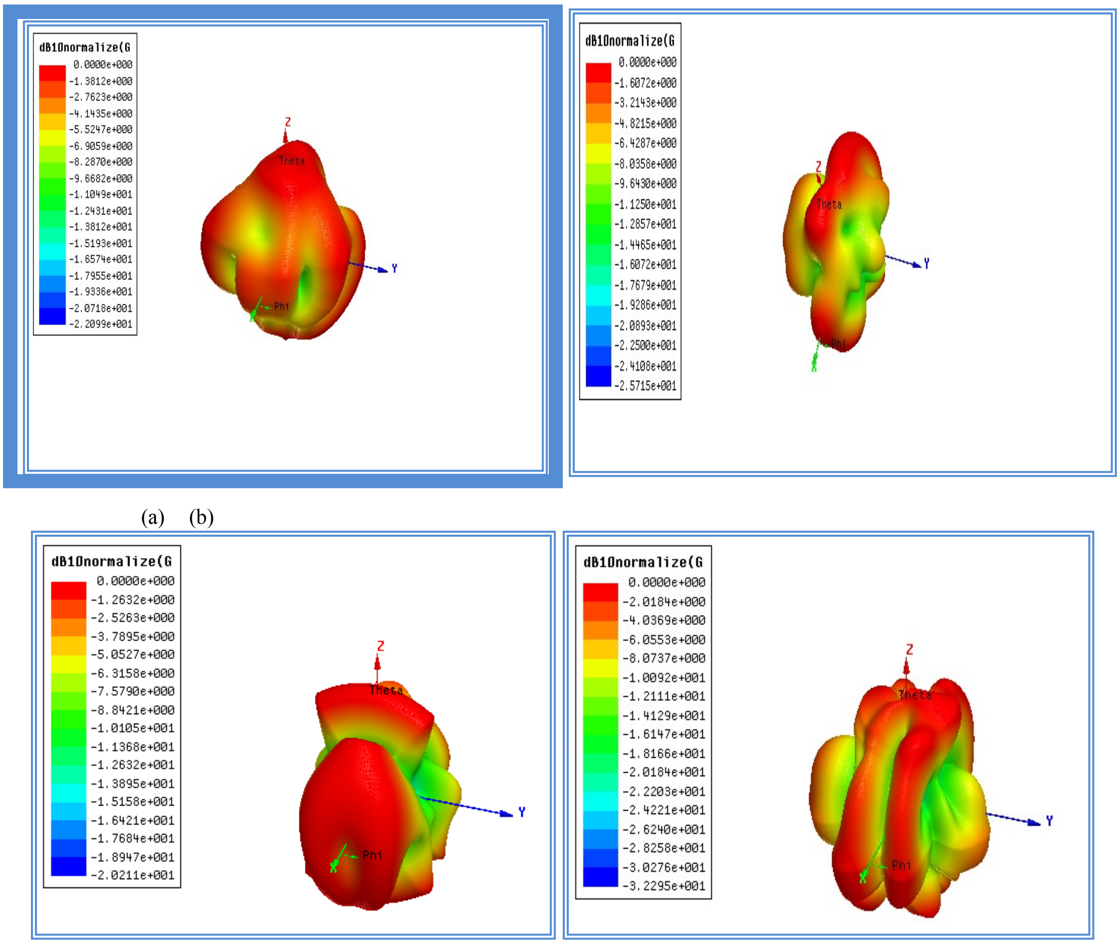
Electrical Properties	Nanosatellite Application		GPS-SAR Application		LTE System	
	Number of Lungs Patch Element		Number of Lungs Patch Element		Number of Lungs Patch Element	
	Single	Two Elements	Single	Two Elements	Single	Two Elements
Reflection coefficient (dB)	- 14.36 (simulated)/ - 21.99 (measured)	-22.99 (simulated)/ -12.52 (measured)	-32.23 (simulated)/ -12.141 (measured)	-17.969 (simulated)/ -12.032 (measured)	-27.96 (simulated)/ -1.64 (measured)	-10.96 (simulated)/ -11.355 (measured)
Impedance bandwidth (MHz)	50 (simulated)/ 50 (measured)	53 (simulated)/ 53 (measured)	50 (simulated)/ 50 (measured)	>100 (simulated) />100(measured)	50 (simulated)/ 50 (measured)	>220 (simulated) / >220 (measured)
VSWR	< 2 (simulated)/ 1.17 (measured)	1.15 (simulated)/ 1.6 (measured)	1.05 simulated)/ 1.85 (measured)	1.29 (simulated) /1.69 (measured)	< 2 (simulated)/ 1.74 (measured)	1.86 (simulated)/ 1.721 (measured)
Axial Ratio (dB)	-	7.2 (simulated)	-	2.3 (simulated)	-	2.29 (simulated)
Beamwidth $(^0)$	Approx. 120 (simulated)/ Approx. 80 (measured)	Approx. 70 (simulated)/ Approx. 80 (measured)	Approx. 90 (simulated)/ NA	Approx. 45 (simulated)/ NA	Approx. 55 (simulated)/ NA	Approx. 25 (simulated)/ NA
FTBR (dB)	Approx. 15 (simulated)/ Approx. 15 (measured)	Approx. 14 (simulated)/ Approx. 5 (measured)	Approx. 7 (simulated)/ NA	Approx. 10 (simulated)/ NA	Approx. 12 (simulated)/ NA	Approx. 14 (simulated)/ NA



(a) (b)

(c) (d)

Fig. 2. The manufactured lungs patch antennas: (a-b) a single and two elements for GPS-SAR application; (c-d) a single and two elements for LTE application.



(a) (b)

(c) (d)

Fig.3. The 3D-patterns of the constructed lungs antennas: (a) a single lungs GPS-SAR antenna, (b) two elements array of lungs GPS-SAR antenna, (c) a single lungs LTE antenna, and (d) two elements array of lungs LTE antenna.

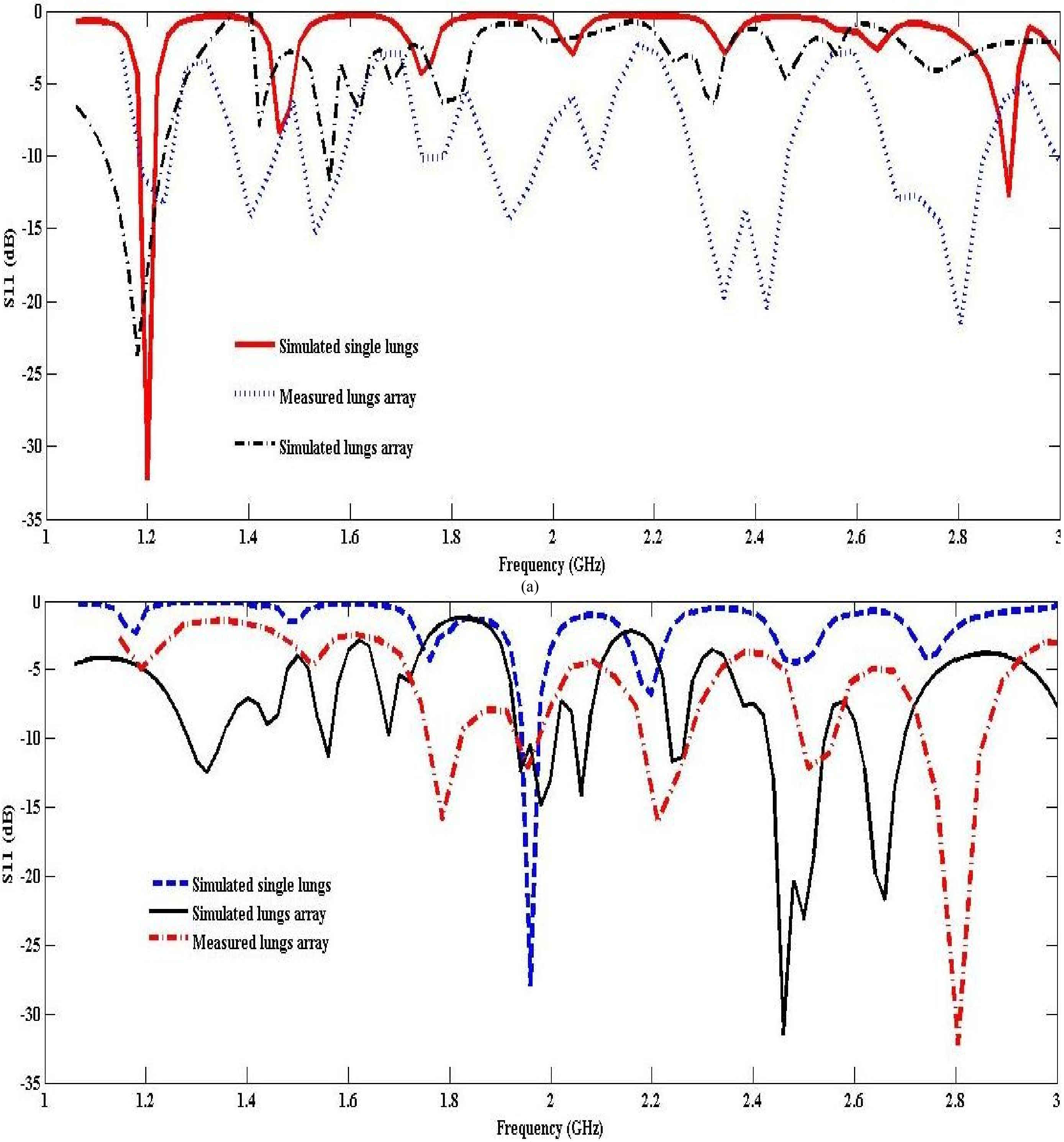


Fig.4. The reflection coefficient of the designed lungs antennas: (a) a GPS-SAR antenna 1.2 GHz, (b) a lungs LTE-BTS antenna 1.98 GHz.