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An Ultrawideband MIMO Antenna using QSCA

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***Abstract*—We know that wireless communication is an advanced technology. Current wireless communication requires high bit-rate transmission to support various multimedia services. In this paper, a compact ultrawideband (UWB) multiple- input–multiple-output (MIMO) antenna with lower wireless local area network (WLAN) coverage is proposed. The proposed MIMO antenna consists of two quasi-self-complementary monopoles, which are easy to achieve ultrawideband operation. By arranging two monopoles symmetrically, with their main radiation directions oppositely oriented, a UWB MIMO antenna with high isolation is proposed. This high isolation is achieved without using any other decoupling methods, which, totally, benefits from the monopoles' complementary and asymmetrical structures. The measured return loss has the band of mainly covering 2.19–11.07 GHz except a little higher than 10 dB at 2.86–3.28 GHz, and with | S_{21} | ≤ -20 dB at most of the band. Since the proposed monopole has excellent inherent properties, a four-element UWB MIMO antenna with good isolation is also discussed.**

***Keywords*—Envelope correlation coefficient (ECC), multiple-input–multiple-output (MIMO), quasi-self complementaryantenna(QSCA),ultrawideband(UWB) antenna.**

I. INTRODUCTION

In thepastdecade,abigproliferationandfastevolutionhasoccurredinwirelessmobilecommunications,whichpushesresearcherstolookforwardandseeknewtechnologiesthatcanprovidemassiveandfastdatatransmission.Multiple-input–multiple-output(MIMO)isamultiplexingtechnologybyadoptingmultiantennasbothattransmitterandreceiver,whichcanenhancethechannelcapacityby takingfulluseoftherichscatteringenvironmentandwithoutsacrificingadditionalspectrumorpower[1],[2].Foritsoutstandingperformances,MIMOtechnologywillbewidelyusedinthenextgeneration ofwire-lesscommunications.Meanwhile,ultrawideband(UWB)isalsoanothertechnologythatcanprovidemassivedatatransmissionatatimebyoccupyinganextremelywidefrequencyband.Forreducingpowerconsumptionandinterferenceswithotherprotocols,itssignaltransmissionis confined in a very low level, which is under 41dBm/MHz [3]. Since the Federal Communications Commission (FCC) released 3.1–10.6 GHz for unlicensed accessing and commercial use [3], UWB technology has been extensively studied, and lots of UWB antennas have been reported. Thus, to reach a high data rate, even as high as 1 Gb/s, a more advanced technology should be used. A combination of MIMO and UWB technology may be a good solution, which has been first reported systematically by Kaiser *etal.*

Until now, several reports on MIMO antenna of UWB can be reached, in which different methods have been taken to obtain a good isolation. By placing antenna elements orthogonally, i.e., their radiation orientations are orthogonal, [5] achieves a high isolation (|S_{12}| ≤ -20 dB) at 3.1–5.15 GHz. Reference [6] proposes a UWB MIMO antenna (2.27–10.2 GHz) by placing elements far enough and inserting parasitic stubs between them to achieve a high isolation at most of the band. Reference [7] reveals a wide antenna (3.1–5 GHz) that works in the lower UWB range, in which a high isolation (S_{12}| ≤ -20 dB) is achieved by monopoles' orientation rotations and ground plane cut. In [8], a treelike structure was inserted between two elements to achieve a good isolation (S_{12}| ≤ -20 dB) of the proposed UWB MIMO antenna. For all the mentioned UWB MIMO antennas above, some kinds of decoupling methods are inevitably used to achieve good isolations. This is always the common and effective way to do that, but the decoupling structures, more or less, occupy spaces in the MIMO antenna. Some of them make the MIMO antenna design more complicated, while the others make its size larger.

In this paper, a completely different concept is proposed in which high isolation in an MIMO antenna can be achieved without using any extra decoupling structures or methods. This can be achieved by adopting antenna elements with obvious asymmetrical structures and radiation orientations. Quasi-self-complementary antenna (QSCA) is one of them and also has a wideband operation, and there are many re- ports that can be found, such as [9]–[11]. As an example, a UWB MIMO antenna with lower wireless local area network (WLAN) coverage is proposed in this letter, and a type of quasi-self-complementary UWB monopole antenna is selected as element. To fully investigate the potential of the selected UWB monopole antenna, not only a two-element UWB

MIMO antenna is proposed, but a UWB MIMO antenna with the same four elements is also discussed.

II. TWO ELEMENTUWB MIMO ANTENNA DESIGN

A. AntennaElementDesignandDiscussion

Fig. 1 shows the geometry of the proposed quasi-selfcom-plementary UWB monopole, which is compact in size with dimensions of 21×30 mm^2 . It is printed on an FR4 substrate,which is supported in HFSS material assignment, with 1-mm thickness, 4.4 permittivity, and 0.02 loss tangent. The proposed UWB monopole consists of a semi-circle patch (with radius) and a complementary cut ground plane (semi-circle cut ground plane with radius R2), which is called QSCA. It is known that a self-complementary antenna is always easy to get a wideband operation for its special structure whose input impedance is always independent to the frequency variation.

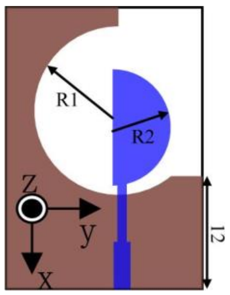

Fig. 1.Geometry of the UWB quasi-self-complementary monopole.

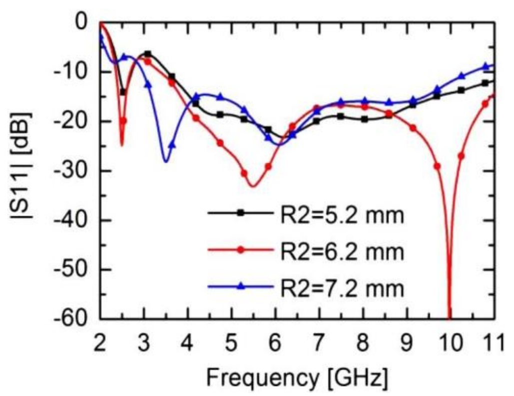

Fig. 2. Simulated $|S_{11}|$ of the proposed monopole varies with the patch Radius R_2 .

Although the monopole that we proposed in this letter is not the strictly self-complementary antenna, it also has the similar operation properties. Fig. 2 depicts the variations of simulated monopole can achieve an ultrawideband operation easily even if the patch size changes dramatically.

Due to the asymmetry structure of the QSCA, it owns some inherently directional radiation properties, which means the monopole radiates to a fixed direction. Fig. 3 gives the simulated radiation patterns of the proposed monopole at 2.45,4, 6, and 8 GHz with R_2= 6.2 mm. It can be seen that the rEφin y0z – and xoz -planes is one-direction-pointed, and its main radiation directions aim to y -axis. It indicates that when two proposed monopoles are put together with main radiation directions oppositely oriented, a good isolation may be obtained inherently.

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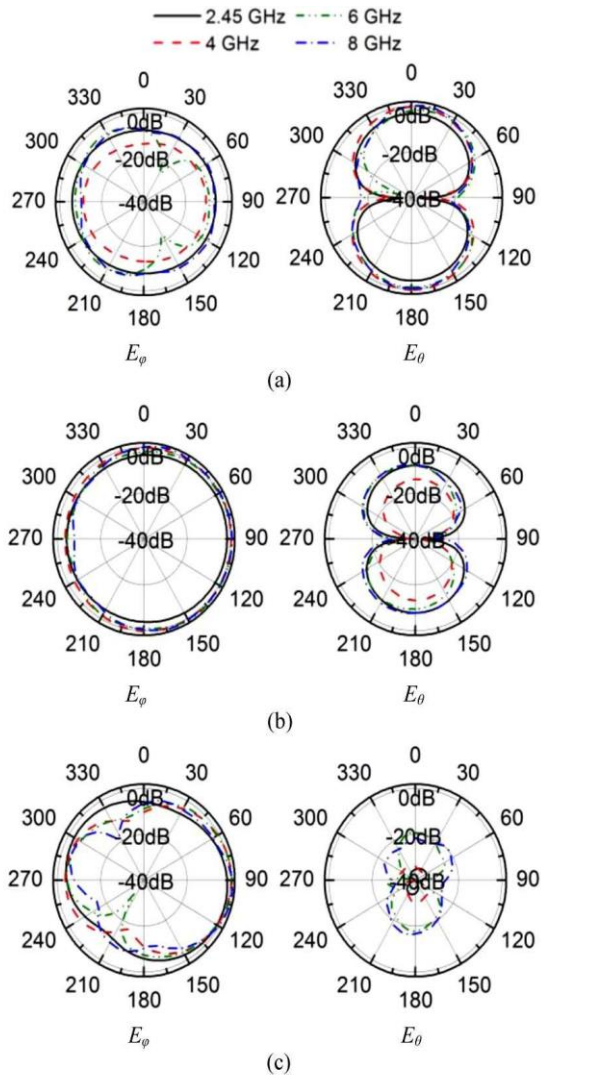

Fig. 3. Simulated radiation patterns of the proposed monopole at 2.45, 4, 6, and 8 GHz. (a)x0z -plane, (b)yoz -plane, and (c) xoy -plane.

B.ProposedTwo-ElementUWBMIMOAntenna

As mentioned above, two proposed monopoles are put to-gether with their main radiation directions oppositely oriented, and then a UWB MIMO antenna with high isolation is proposed. Fig. 4 shows the geometry and dimensions of the proposed UWB MIMO antenna. It is printed on a substrate that is the same as the monopole used above Fig. 5 gives the surface current distributions of the proposed MIMO antenna at 2.45,4, 6, and 8 GHz when Port_1 is excited and Port_2 terminated with 50 Ω , where it can be seen that the currents mainly concentrate at the edges of the patch or the ground plane. This is also true for a QSCA, where the excited patch and its complementary ground plane are all parts of the antenna. Owing to this, edge isolation of the proposed compact UWB MIMO antenna can be inherently obtained without using any extra decoupling methods.

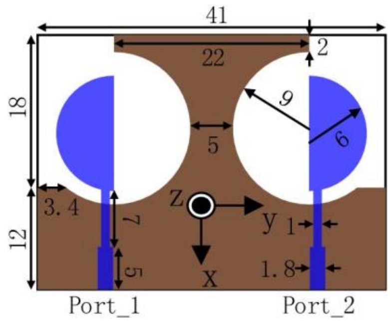

Fig. 4. Dimensions of the proposed compact UWB MIMO antenna (unit: millimeters).

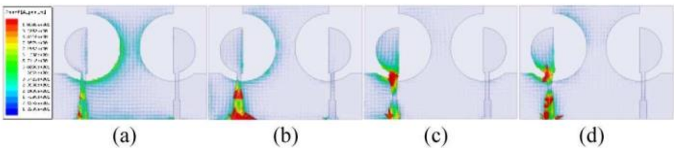

Fig. 5. Surface current distributions of the proposed compact UWB MIMO antenna at 2.45, 4, 6, and 8 GHz with Port_1 excited and Port_2 terminated.

C.ResultsandDiscussions

As an example, the model in Fig. 4 has been fabricated and measured, and its numerical simulations are implemented in HFSS ver. 15.0. As a note, the antenna fabrication is taken on an FR4 substrate with 4.4±0.2 permittivity. Its prototype and S-parameters are shown in Fig. 6. It can be seen that the simulated results cover 2.14–11.4 GHz with $|S_{11}| \leq -20$ dB and $|S_{12}| \leq -20$ dB. (within most of the band), while the measured $|S_{11}|$ curve has the band of mainly covering 2.19-11.07 GHz except 2.86–3.28 GHz, which is a little higher than -10 dB and in -9.1dB, and also $|S_{12}| \leq -20$ dB at most of the band. The disagreements and shifts between the simulated and measured results may due to the inaccuracy of the substrate permittivity and SMA connections. Fig. 7 shows the measured radiation patterns of the proposed compact UWB MIMO antenna at 2.45, 4, 6, and 8 GHz. However, for simplification, only one measured port (Port_1) is given, and the other is omitted for symmetry. The measured radiation patterns of the two ports show good symmetry and complementary properties, and this also can be found in the given radiation patterns that show one-direction radiation properties. Fig. 8 shows curves of the measured peak gains and total efficiencies, in which the peak gain reaches 6.5 dB and radiation efficiencies in 55%–88%.

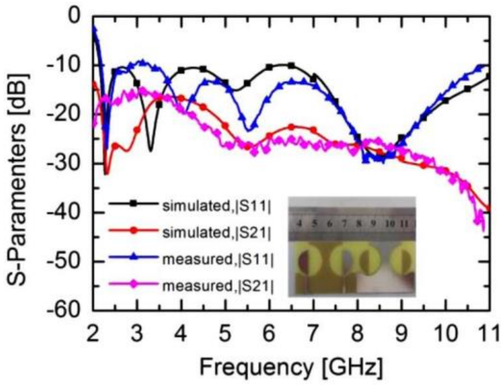

Fig. 6. Simulated and measured S -parameters of proposed compact UWB MIMO antenna.

For an MIMO antenna, envelope correlation coefficient (ECC) is another paramount parameters, which indicates its diversity performances. According to [12], ECC can be calculated from far-field radiation patterns. For a two-element MIMO antenna. The simulated and measured ECCs are shown in Fig. 9 and all below 0.25. For an MIMO antenna, ECC less than 0.25 is low enough to keep a high channel capacity [4].

III. FOUR ELEMENT UWB MIMO ANTENNA

According to the monopole's operation properties, a four element UWB MIMO antenna is also presented. Its model is built in the circumstance of HFSS ver. 15.0, and the antenna is printed on an FR4 substrate, which is the same as above, with total dimensions of 60×41×1mm$^{2.}$ Its geometry is given in Fig. 10, which simply places the two dual-antenna element, UWB MIMO antennas together with ground slot 1 mm between them. The simulated S parameters are shown in Fig.11, where, for symmetry of the two element UWB MIMO antenna above, the four element one can operate at UWB band (3.1-10.6GHz) with higher isolation and better impedance matching. However, for frequencies below 3 GHz, $|S_{23}|$ and $|S_{41}|$ are getting worse, which is because the monopoles surface currents are easy to interact at ±x-directions when frequency is low enough. This can be validated in Fig. 12. It can be seen that the current is obviously coupled to port 2 and port 3 at 2.45 GHz, while it is much less at 4, 6, and 8 GHz. Four element MIMO antenna can only cover the UWB band, but better impedance matching and isolation are achieved. In MIMO applications, the signals transmitted by multiple antenna elements are generally supposed to be independent or uncorrelated.

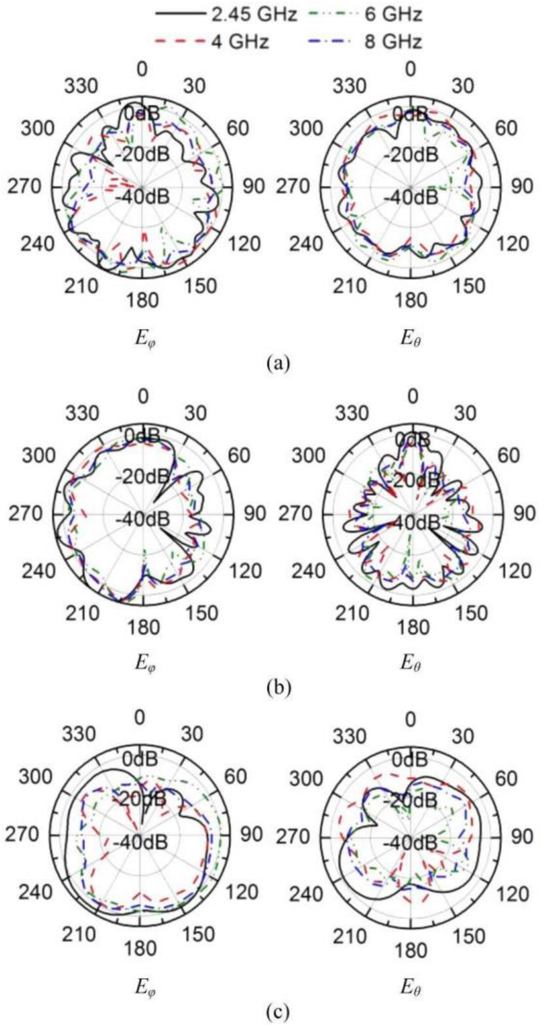

Fig. 7. Measured radiation patterns of the proposed compact UWB MIMO antenna at 2.45, 4, 6, and 8 GHz with Port_1 excited. (a) xoz -plane, (b)yoz -plane,and (c) xoy -plane.

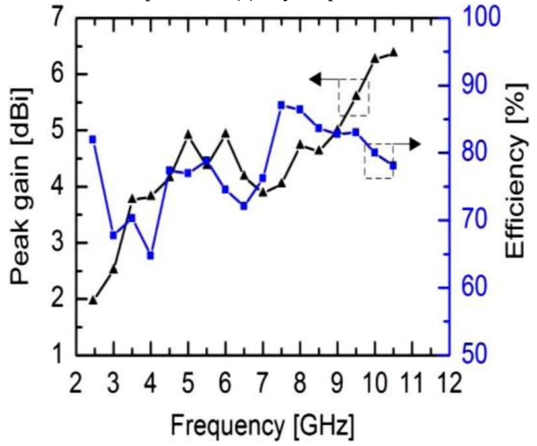

Fig. 8.Measured peak gains and total efficiencies.

But in reality, the current induced on one antenna produces a voltage at the terminals of nearby elements, termed as mutual coupling. Now it means there is always mutual coupling present between nearby antenna elements. However, for MIMO applications, the mutual coupling should be minimized to as low value as possible.

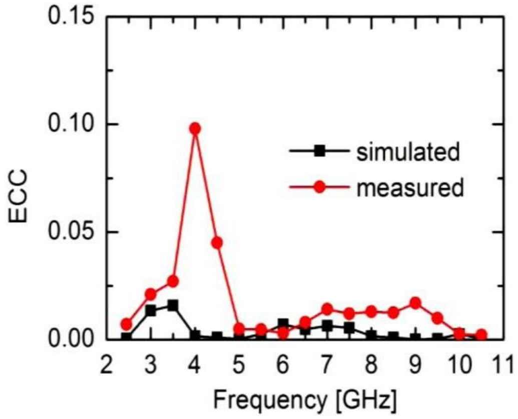

Fig. 9. Simulated and measured ECC of the proposed UWB MIMO antenna

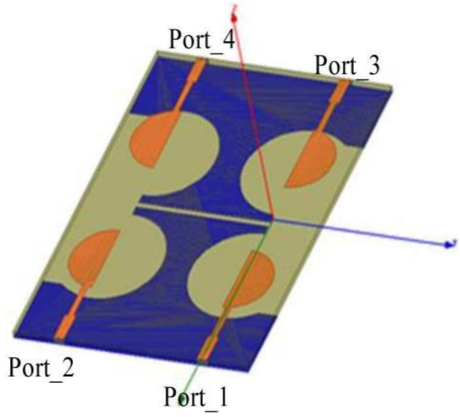

Fig. 10.Geometry of the four-element UWB MIMO antenna.

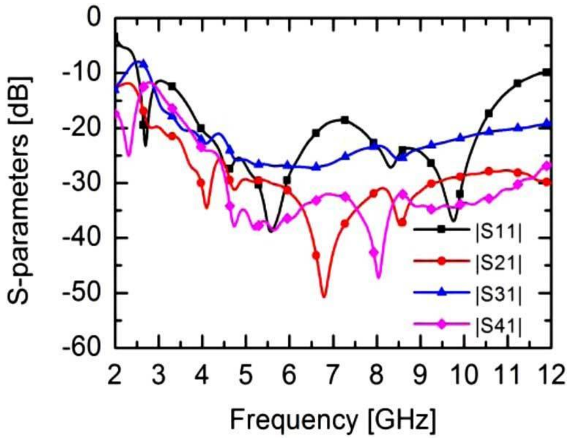

Fig. 11. Simulated -parameters of the four-element UWB MIMO

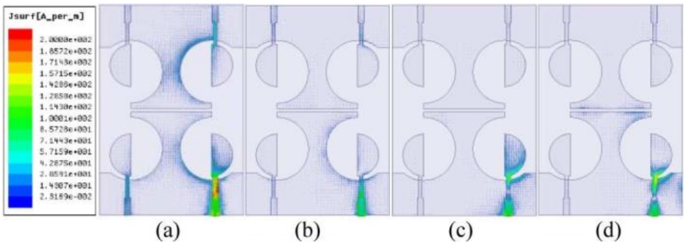

Fig. 12. Surface current distributions of the four-element UWB MIMO

IV. CONCLUSION

A compact two-element UWB MIMO antenna, with WLAN coverage, is proposed in this paper.Multiple-input multiple-output (MIMO) is a multiplexing technology by adoptingmultiantennas both at transmitter and receiver, which can enhance the channel capacity.For its outstanding performances, MIMO technology will be widely used in the next generation of wireless communications. Meanwhile, ultrawideband (UWB) is also another technology thatcan provide massive data transmission at a time by occupying an extremely wide frequency band.With the good performances and properties of the proposed QSCA UWB monopole, an inherently high isolation is easily achieved without any decoupling methods used. As discussed in Section II, the proposed two-element MIMO antenna is easy to achieve a good impedance matching since antenna elements performance is insensitive to its structural change. The proposed compact two element UWB MIMO antenna can work from 2.19 to 11.07 GHz, which may be a nice candidate for lower WLAN (2.45 GHz) and UWB (3.1–10.6 GHz) applications. Then, a four-element UWB MIMO antenna is also presented and discussed. As a price of four elements, the four-element MIMO antenna can only cover the UWB band, but better impedance matching and isolation are achieved. Future work is to change the shape of groundplane and obtaining high isolation more than -20 dB.

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