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A New Compact Two-Port Microstrip Antenna

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Abstract:- In this paper, a new compact microstrip antenna structure having two physically separated ports (180^o orientation) has been proposed, designed and presented. Each antenna port resonates at a different single frequency (or dual frequencies) within the 4G band (broadband and/or wideband), and it has high port-to-port isolation (below -22.0 dB). The antenna design is mainly based upon a novel reconfigurable ground structure (shape, dimensions and location). The full ground of microstrip antenna has been partitioned into three isolated ground strips, each one having a specific width and length. The orientation of these strips is perpendicular to the feeders, and each strip has two (or more) slots of different geometries. Such ground configuration is referred to as Defective Digital Ground Structures (DDGS). The proposed microstrip antenna has been simulated using the CST_MW studio, and it has been mounted on a cheaper FR4-substrate to verify the proposed design. Simulation results showed that for each antenna port, resonance frequencies, operating bands and isolation can be adjusted using the proposed DDGS to achieve the desired antenna specifications. Thus, DDGS is simply representing built-in resonance and decoupling circuits with no additional cost for antenna design. The presented study offers a new practical and simple approach to solve the multiport antenna design problem.

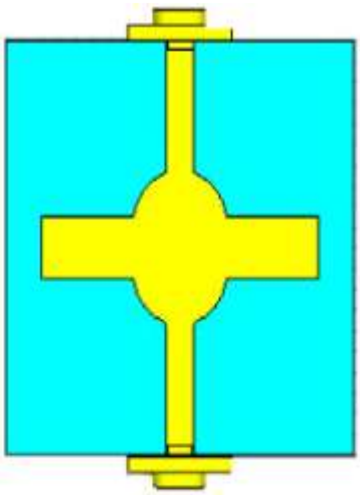
Keywords:- Two-Port Planar Antennas, Microstrip Two-Port Antennas, Dual Two-Port Antennas

I. INTRODUCTION

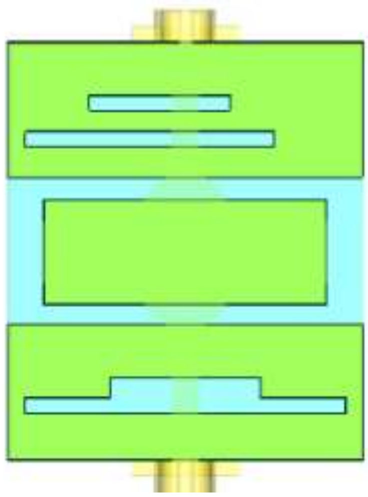
Performance of wireless communication systems has been extremely improved using multiple inputs multiple outputs antenna structures (MIMO) [1-9]. This includes space diversity, channel capacity, and minimum cross coupling between different antennas and/or ports. On the other hand, a single arbitrary patch antenna structure having more than one port is also another important target to enhance the performance capability of the wireless communication systems using MIMO antenna configurations. However, a little work has been done for designing a single microstrip patch antenna structure having two ports and/or multiport, each one resonates at different frequencies [10-12]. In addition, coupling between ports is one of the main challenges for designing and optimizing of the two-port antenna. In fact, the need for a microstrip patch antenna structure having N-ports is an essentially demand to accommodate the multifunction constrains of communication systems. Consequently, this leads to compact array size, overall cost reduction, higher channel capacity and space diversity enhancement. Such a single patch antenna is referred to as multi-port planar antenna structure. In addition, use of a single substrate microstrip structure is preferable for designing multi-port antenna mounted on the main motherboard. This is due to the excellent compatibility with the typical manufacturing process of MMIC planar circuits as well as elimination of dielectric discontinuity of the antenna chip. In this paper, a new compact two-port microstrip antenna has been proposed and presented. This antenna design achieves unique and superior space and frequency diversities as compared to all other published work. The proposed antenna has a novel reconfigurable ground structure having isolated defective strips. Such antenna ground is referred to as defective digital ground structure “DDGS”. In fact, it has been utilized to design the proposed two-port antenna structure. The use of such DDGS alternates the equivalent current source of patch antenna seen by each port. Thus, the antenna resonance of each port can be easily controlled as well as the associated frequency band within the 4G band. Three main constrains must be practically considered in designing and optimizing an efficient two-port planar antenna structure. These are the overall antenna size, the antenna effective operating bandwidth, and the mutual coupling between ports. Therefore, these constrains represent the real challenge for antenna designers. Therefore, an efficient two-port antenna structure should be compact in size, broad in frequency, and highly isolated ports. Furthermore, the overall antenna characteristic must be optimized over the individual operating frequency band for each port. The present paper is organized among three main sections. The second section, presents a detailed description of the proposed two-port microstrip patch antenna. This antenna has three different defective digital ground structures to demonstrate how resonance and bandwidth of each port can be controlled. The proposed antenna has been simulated using the commercial microwave simulator (CST), and the results of different antenna configurations are discussed, compared, and presented in the third section. Finally, the last section concludes the presented paper.

II. ANTENNA COFIGURATION AND DESCRIPTION

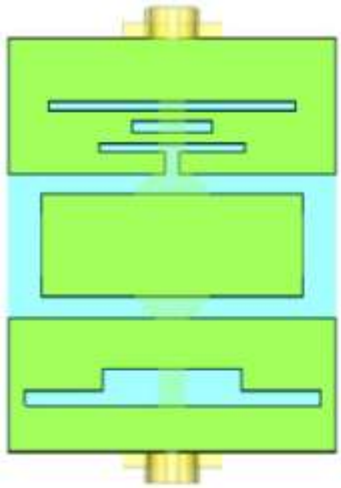
The proposed two-port microstrip patch antenna having three reconfigurable ground structures is presented in Fig.1 (a) through Fig.1 (d). The patch antenna consists of two symmetric Mexican Hats; one hat is flipped, and then connected to the other hat (upper hat and lower hat). Each hat is composed of a half circle of equal radius and a rectangular strip of equal dimensions (Rect.). This patch is mounted symmetrically on the substrate, and it is fed with two identical transmission lines. These lines are perpendicular to the patch and they are 180^{o} orientation. Each transmission line represents a single port, and it is connected to SMA connector. The antenna feeders are assumed to be 50 Ohm, and they have lengths of 13.0 mm (L_f) and widths of 3.3 mm (W_f). The proposed patch is mounted on FR-4 substrate (ε_r=4.7, 1.6 mm height, and tangential loss of 0.025) with conductor thickness is assumed to be 0.035mm. This substrate has a square shape of a length equal to 40.0 mm (L_s=W_s=40.0 mm). The antenna ground plane is a defective digital ground structure shape (DDGS). It consists of three isolated ground strips having arbitrary a rectangular geometry. The ground strip under each feeder has the same substrate width and different lengths as shown in Fig.1 (b) through Fig.1 (d). These strips have different number of slots with different shapes. The middle strip has different width and length, and it has no slots. The patch dimensions and locations are presented in Table 1. Optimized dimensions and locations of the three DDGS planes are summarized and illustrated in Table 2. The slots under feeders are arranged in ascending order in a direction from port #1 to port #2. In other word, the first Slot_1j starts from port #1 and ends to the second edge of the first strip (j=1, 2,..,5) where as the Slot_2j starts from the first edge of third strip and ends to port #2 (j=1,2, …., 4).



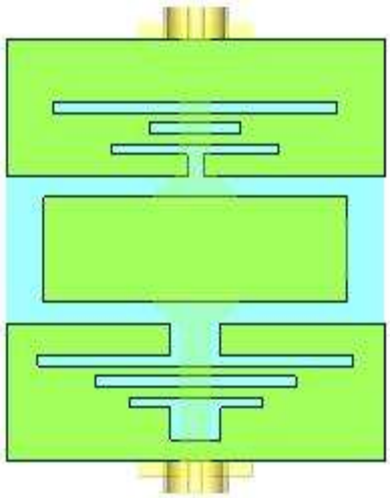
(a) Patch top View (x-y plane)



(b) Bottom view of DDGS #1



(c) Bottom view of DDGS #2



(d) Bottom view of DDGS #3

Fig.1 Proposed Two-Port microstrip antenna configuration

Table 1 Dimensions and locations of the proposed patch

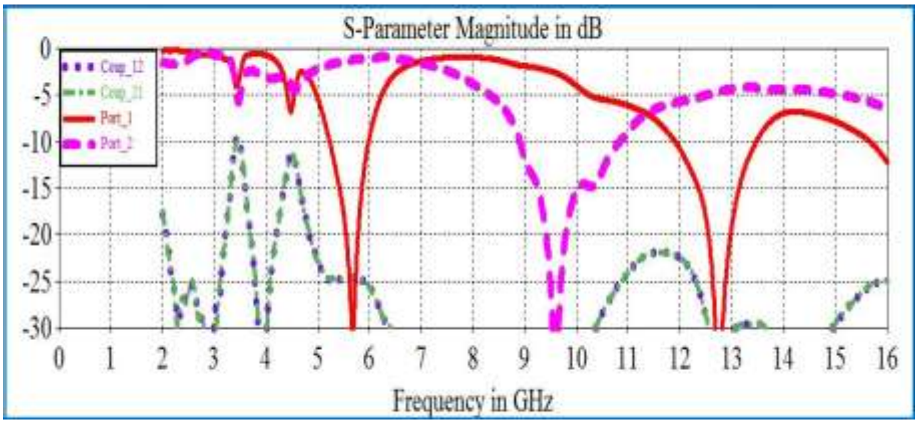
Symbol	X Location or (Center)	Y Location (Center)	Length or (Radius)	Width
Feeder #1	20 -W_f/2 20+W_f/2	0.0 L_f	L_f	W_f
Feeder #2	20-W_f/2 20+W_f/2	40 - L_f 40	L_f	W_f
Upper Circle	20	18	5.5	-
Lower Circle	20	22	5.5	-
Rect	4 36	17 23	6	32

Table 2 Optimized dimensions of the proposed DDGS

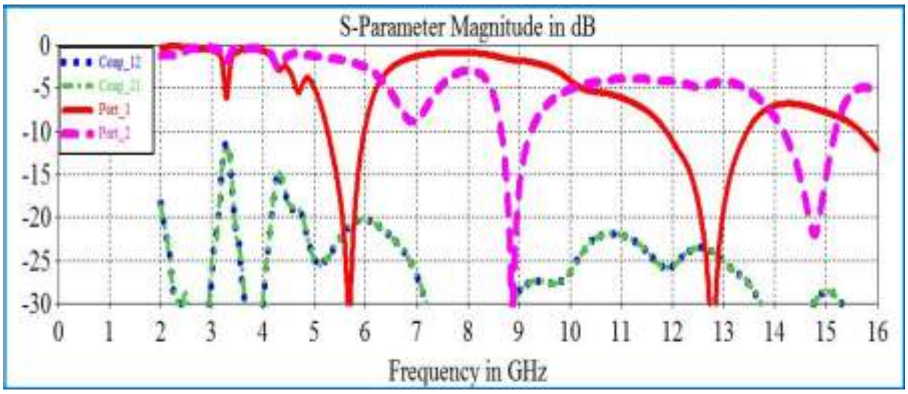
		Locations (x_i, x_j) & (y_i, y_j) of each ground strip/slot in mm, where $W_k=(x_j-x_i)$, $L_k=(y_j-y_i)$ are the corresponding the widths and lengths		
		DDGS #1	DDGS #2	DDGS #3
Strip Under Feeder #1		(0, W_s) (0, 13)	(0, W_s) (0, 13)	(0, W_s) (0, 13)
Strip Under Feeder #2		(0, W_s) (27,L_s)	(0, W_s) (27,L_s)	(0, W_s) (27,L_s)
Middle strip Under patch		(4, 36) (15, 25)	(4, 36) (15, 25)	(4, 36) (15, 25)
Port # 1	Slot_11	(2.0, 38) (4.5, 6.0)	(2.0, 38) (4.5, 6.0)	(20 - 4 W_f/5, 20 + 4 W_f/5) (2, 5)
	Slot_12	(11.5, 28.5) (6.0, 8.0)	(11.5, 28.5) (6.0, 8.0)	(13, 27) (5, 6)
	Slot_13	-	-	(12 - 4W_f/5, 28 + 4W_f/5) (7, 8)
	Slot_14	-	-	(6 - 4W_f/5, 34 + 4W_f/5) (9, 10)
	Slot_15	-	-	(20-4 W_f/5, 20 + 4 W_f/5) (9, 13)
Port # 2	Slot_21	(2.0, 30)	(20 – W_f /4, 20 +W_f/4) (27, 29)	(20 – W_f /4, 20 + W_f/4) (27, 29)
	Slot_22	(30, 31.5)	(12-W_f/4, 28+ W_f/4) (29, 30)	(12- W_f /4, 28 + W_f /4) (29, 30)
	Slot_23	-	(16- W_f /4, 24+ W_f /4) (31, 32)	(16- W_f /4, 24 + W_f /4) (31, 32)
	Slot_24	-	(5, 35) (33, 34)	(5, 35) (33, 34)

III. SIMULATION RESULTS AND DISCUSSION

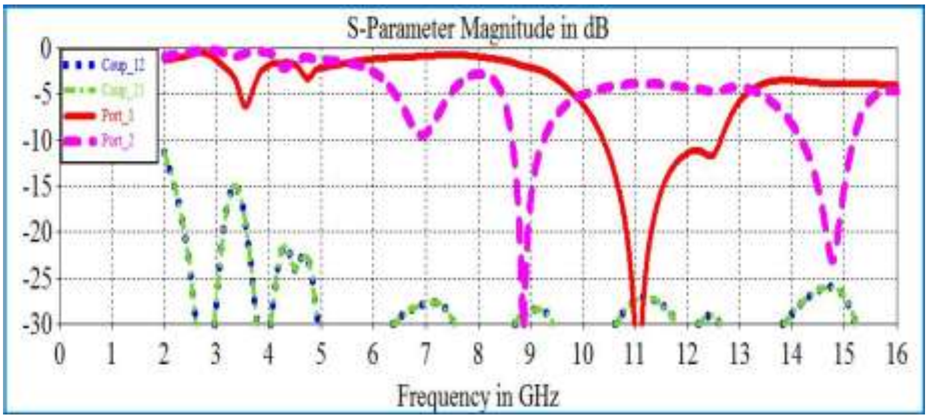
The proposed two-port antenna design has been simulated and investigated using the CST_simulator version_2012. The antenna computational domain is closed by outer PML boundaries. A high dense mesh and thick PML layers are assumed to achieve accurate results in time and frequency domains. The antenna s-parameters have been computed and optimized. Simulation results are presented in Fig.2 (a) through Fig.2 (c). These figures illustrate the scattering parameters for the three different assumed DDGS configurations. As it is clear from Fig.2, DDGS creates a single resonance frequency (or dual) for each antenna port. The center resonance frequency and its bandwidth of each port can be adjusted using the number of DDGS slots and their dimensions and locations. It should be noted that the resonance frequencies of each port is very sensitive to the number of slots per each ground strip as it is clear from the presented figures. Moreover, the coupling between ports is highly dependent on the DDGS configuration. To study the impact of the different DDGS configurations on each port resonances and isolations, the current density should be evaluated, investigated and compared. Thus, the current distributions of the first DDGS configuration (see Fig.1 (b)) is computed and presented in Fig.3 (a) through Fig.3 (c). It is clear that from Fig.3 (a), at the resonance frequency of 5.677 GHz, port #1 is electrically isolated from port #2. In other word, port #2 sees zero (or minimum) equivalent current of port #1. In this case, the two-port antenna structure resonates only due to the signal fed at port #1 independent on port #2. Similarly, the same situation is occurred for the other two resonance frequencies (see Fig.3 (b) and Fig.3 (c)). Therefore, the DDGS acts as a dual built-in resonator circuit for each port as well as decoupling circuit. In fact, the DDGS alters the equivalent current source of the patch antenna corresponding to each port. This leads to vary the effective electric length of the patch and consequently, each port resonance frequencies are adjusted. This great and unique advantage of DDGS simplifies the design problem of multiport planar antenna. Table 3 illustrates a summarization of the basic simulated parameters of the proposed two-port antenna for the three novel DDGS configurations. This includes the maximum antenna gain, the maximum antenna efficiency, the antenna resonance frequencies, the operating antenna band, and the isolation between ports. Table 3(a), presents the antenna parameters for port number one while Table 3(b) illustrates antenna parameters for port #2.



(a) S-parameters of the proposed antenna with the first ground configuration (DDGS #1)



(b) S-parameters of the proposed antenna the second ground configuration (DDGS #2)



(c) S-parameters of the proposed antenna with the third ground configuration (DDGS #3) Figure 2: S-parameter of the proposed two-port microstrip antenna with three different DDGS configurations

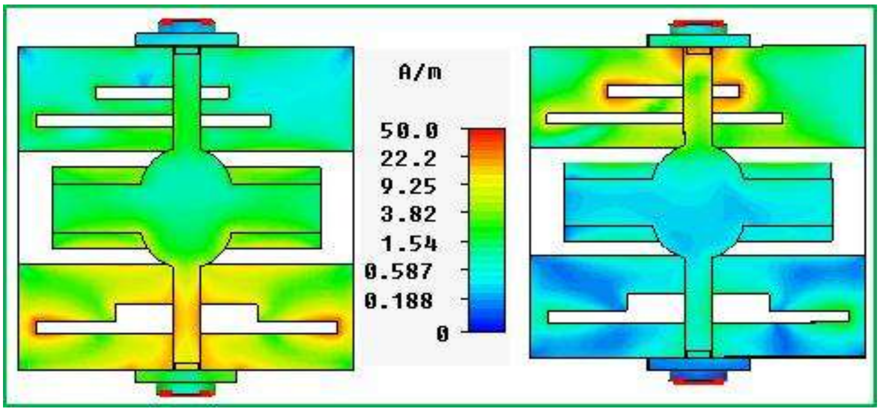
Table 3(a) Antenna Parameters (Port # 1)

	G_o dB	Eff %	F_o GHz	BW MHz	S21/S12 dB
DDGS#1	2.44	82.5	5.677	730	25
	3.16	69.8	12.789	1495	30
DDGS#2	2.44	82.5	5.677	680	22
	3.16	69.8	12.789	1500	24
DDGS#3	4.46	75.6	11.06	2140	28

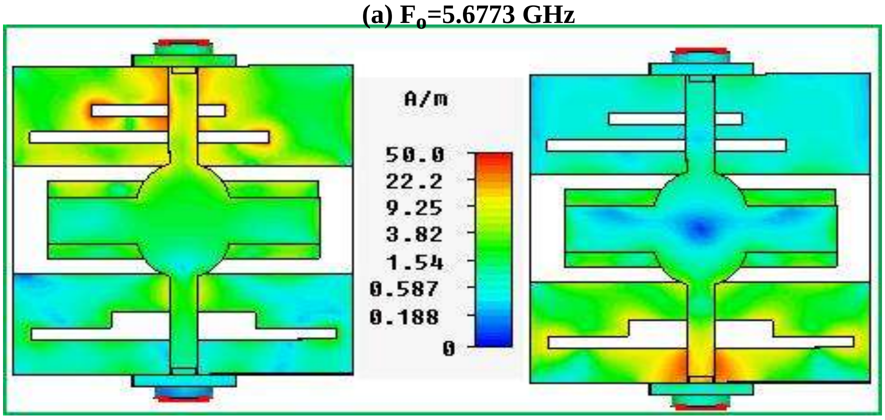
Table 3(b) Antenna Parameters (Port # 2)

	G_o dB	Eff %	F_o GHz	BW MHz	S21/S12 dB
DDGS#1	4.48	72.3	9.597	1950	30
DDGS#2	4.84	66.4	8.869	580	30
	4.36	71	14.777	1000	28
DDGS#3	4.84	66.4	8.869	580	28
	4.36	71	14.777	1000	26

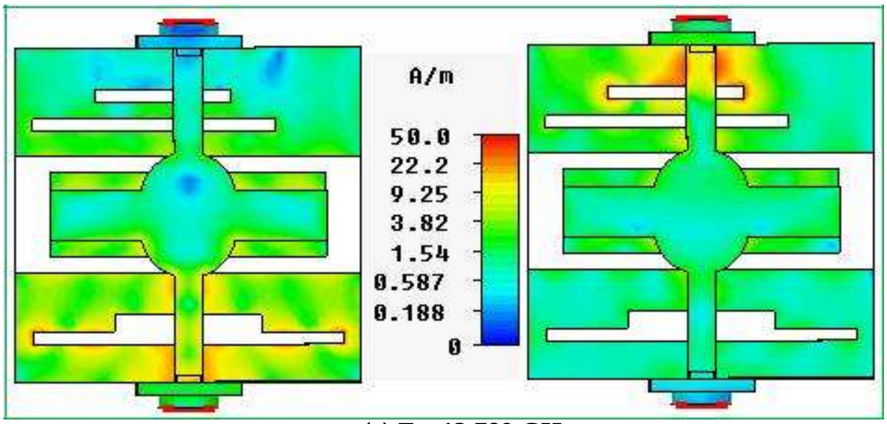
The radiation pattern of the two-port antenna is compute for all antenna resonance frequencies, and presented in Fig.4 (a) through Fig.4 (b). The radiation pattern of first port is very sensitive to the DDGS geometry in particular at higher frequencies as it is clear from Fig.4 (a). The radiation pattern is almost asymmetric Omni-directive pattern with relative offset to the main direction ($\Theta_S=0^0$). The same results are obtained for the second port (see Fig.4 (b)).



(a) F_o=5.6773 GHz

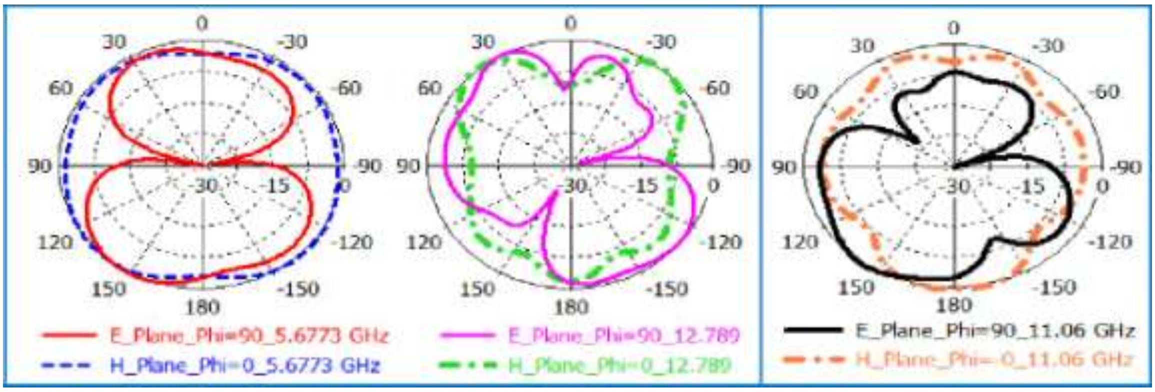


(b) F_o=9.5973 GHz

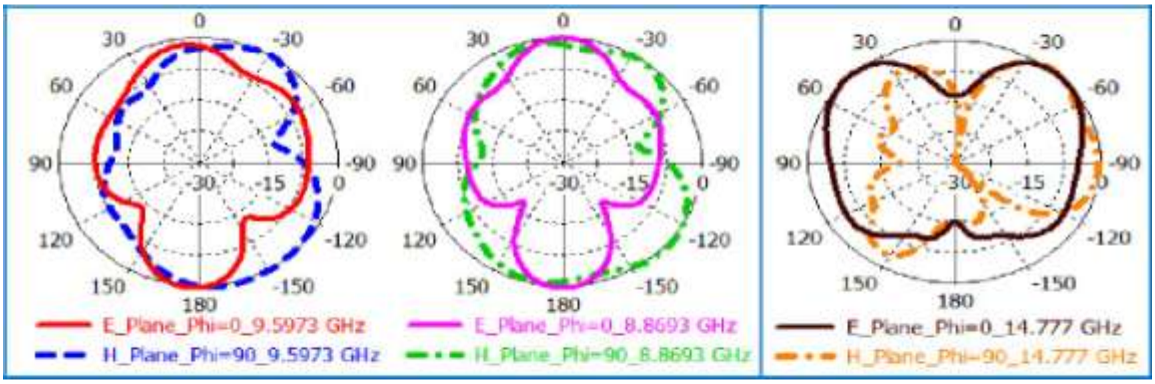


(c) F_o=12.789 GHz

Figure 3: Current density distribution of proposed two-port antenna with DDGS #1 at three resonance frequencies



(a) Radiation pattern of port #1 of the proposed two-port antenna for different DDGS geometries



(b) Radiation pattern of port #2 of the proposed two-port antenna for different DDGS geometries
Figure 4: Radiation pattern of the proposed two-port antenna for different DDGS configurations

IV. CONCULUSION

A New compact two-port microstrip antenna structure has been proposed, designed, analyzed, and simulated using the CST_Studio. The results of simulation showed that the resonance frequencies of each antenna port are very sensitive to the proposed DDGS. In addition, the coupling between ports is highly dependent on the DDGS configuration pattern. Moreover, the surface current density of different resonance frequencies for each port proved that the antenna ports are electrically and physically isolated. Consequently, for each antenna port, resonance frequencies can be controlled within different isolated operating bands. Therefore, based on the obtained results, the novel ground structure (DDGS) acts as dual resonator and decoupling circuits built-in within the antenna structure with no additional cost. In summary, to design such two-port antenna, four steps are required to be performed sequentially. The first step is to design a conventional microstrip patch antenna of suitable dimensions and full ground plane to resonate within the 4G band. Second, divide this ground plane into three isolated partitioned strips (number of ports plus one) to form a digital ground. Then, add arbitrary slots (shape, dimensions and locations) to each ground strip under the antenna feeders to adjust the resonance frequencies for each port. The last step is to optimize the dimensions and location of ground slots to tune the antenna for the required operating frequency bands. These steps have been verified using three different DDGS configurations for the same patch antenna dimensions and geometry. In conclusion, the presented paper introduces a new and simple approach for designing a two-port antenna to operate at the desired frequency bands. Future work will include design of multiport (three and/or four) antenna for MIMO applications.

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