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Design Comparison of Defected Ground Structure Shapes for Microstrip Antenna Miniaturization

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Abstract

DGS is a method by defecting the ground plane of the microstrip antenna. By using this method, the antenna become more compact than the dimension of the conventional size. This paper present comparison of defected ground structure shapes effect to the size of the antenna. Antenna DGS of dumbbell shape, complementary split ring resonator and U shape are investigated and analyzed. From the result, it shows that by using dumbbell shape it achieve size reduction 12.965% from its conventional size, for the complementary split ring resonator the antenna size decreasing above of 47.738% from conventional size meanwhile for U shape provide up to 37.735% size reduction of conventional antenna.

Keywords; *defected ground structure; microstrip antenna; dumbbell shape; U shape; complementary split ring resonator;*

I. INTRODUCTION

Microstrip antenna is popularly used in portable devices for wireless communication system such us Wi-Fi application and mobile communication because of its light weight and low profile. In portable devices we need the compact and small antenna. So reducing antenna size is significant in portable devices.

The DGS is an etched off the shape on ground plane of the antenna which disturbs the current distribution resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer [1].

Some previous researches have been done to reduce the antenna size by using defected ground structure. In paper [2] [3] miniaturization is achieved by using multi rings with slot and three ring shape elements are etched in MIMO antenna [4]. Ring with slot is also introduced in paper [5] to miniature proximity coupled antenna. Different shapes of DGS structure have been introduced, such as dumbbell shape [6] for high isolation port, complementary split ring resonator [7] and U shape [8] for mutual coupling reduction.

This paper present a single and periodic DGS dumbbell shape, complementary split ring resonator and U shape to compare the reduction of the antenna size in the same resonant frequency. Each value of variable shapes are varied to obtain the lowest operating frequency.

II. METHODOLOGY

Basically, four rectangular microstrip patch antenna

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were investigated; conventional without DGS and the other with DGS dumbbell shape, complementary split ring resonator and U shape. All antennas were designed to operated at 3.65 GHz frequency by using Ansoft HFSS.

Prior to analizing of the DGS effects on the antenna, an antenna without DGS (shown in Figure 1) was designed following equation from [9],[10].

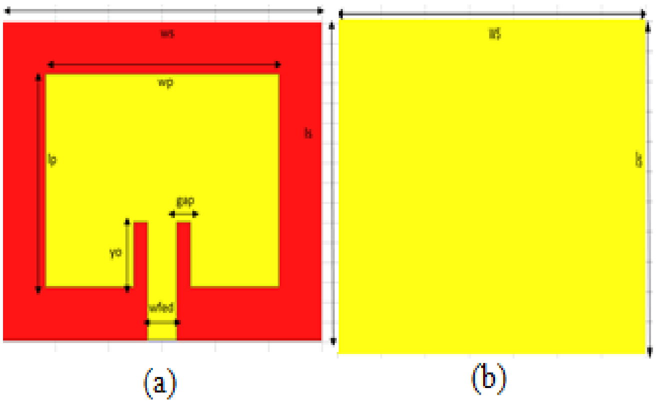

Fig 1 conventional antenna from top (a) and behind (b)

Next figure shows the DGS on single and periodic DGS from dumbbell shape, complementary split ring resonator and U shape that applied on the ground plane of investigated antenna. Every DGS shapes have investigated variable and each of their value are varied so effects on the antenna can be observed.

Figure 2 shows design of dumbbell shape which has four different variables. Variable a is width of the dumbbell, b is length, c is holder of the dumbbell and d is width of the holder. First step was to apply one dumbbell to the antenna ground plane with varying the value of every investigated variable to achieve the lowest operating frequency while maintaining the size of the antenna. The same step was also done for the periodic dumbbell.

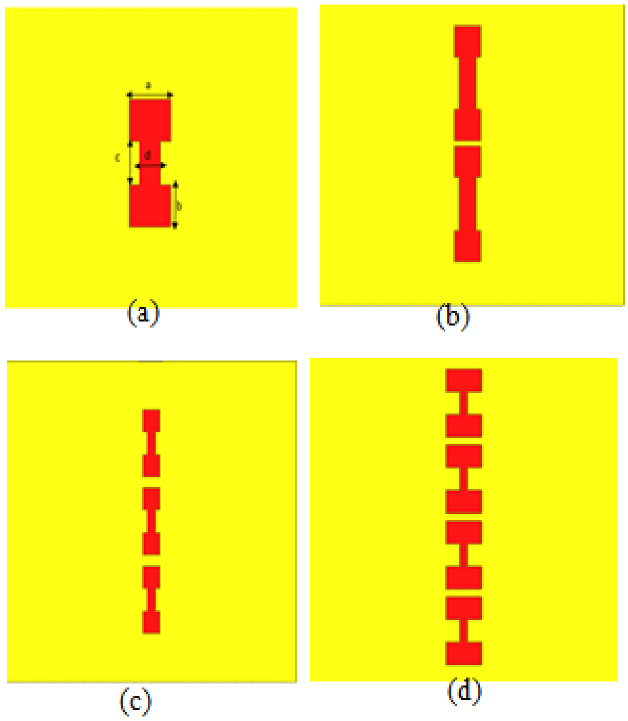

Fig 2. One dumbbell shape (a), two dumbbells (b), three dumbbells (c) and four dumbbells (d)

The design of complementary split ring resonator or CSRR are shown in Figure 3. This DGS shape has four different investigated variables. Variable a is width, b is space between the box, g is the gap and l is CSRR length. Same with the previous design, first step is to add one CSRR and varied the value of each investigated variable by increasing and decreasing the value until it obtain the lowest operating frequency. The same step was also done for the other CSRR.

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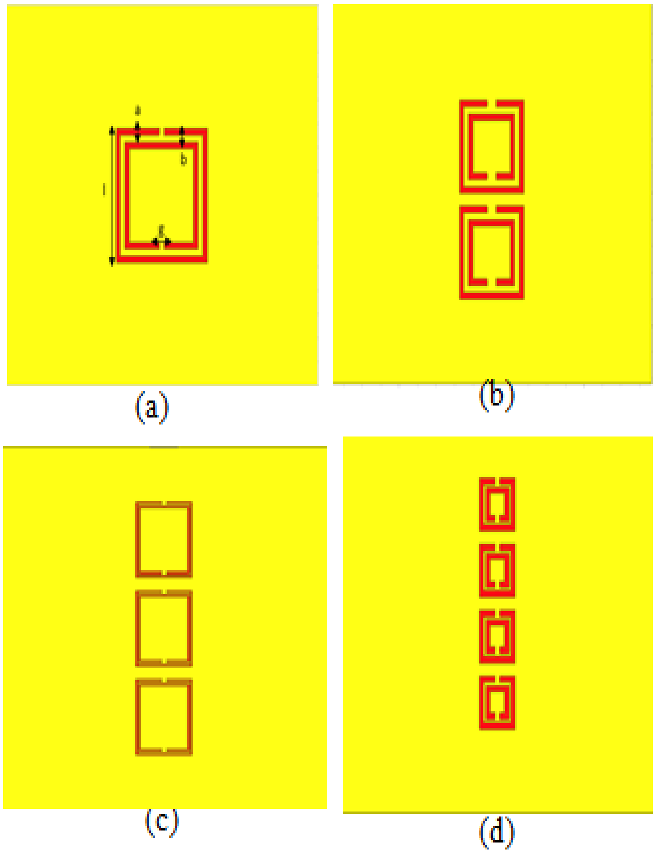

Fig 3. One CSRR (a), two CSRRs (b), three CSRRs (c) and four CSRRs (d)

Figure 4 depicts the design of U shape. This DGS shape has three different investigated variables. Variable n is width of the U, g is the gap and m is the length. Same with two previous DGS design, first step is to add one U shape and varied the value of each investigated variable, until it has the lowest operating frequency. The same step was also done for the periodic U shape.

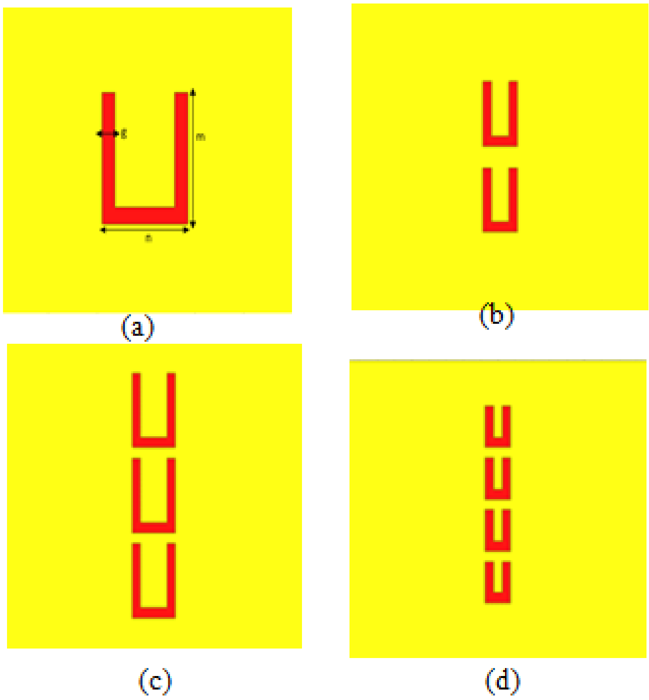

Fig 4. One U shape (a), two U shapes (b), three U shapes (c) and four U shapes (d)

III. RESULTS AND DISCUSSION

Varying the value of each investigated variables from single and periodic DGS will change the peak of resonant frequency. Figure 5 is a graph that presents a VSWR variation from one to four dumbbell shapes with vertical arrangement. This graph come from every maximum result of each simulation by one, two, three and four dumbbell shapes with varying the value of investigated variable.

The design using one dumbbell shape is produce the resonant frequency down to 3.40 GHz with VSWR value is 1.543 whereas for the design of two dumbbell shapes, the resonant frequency decrease down to 3.35 GHz with VSWR value is 1.222. For the design of three dumbbell and four dumbbell shapes, the resonant frequencies were down to the same value of 3.35 GHz with VSWR value is 1.080 and 1.399 respectively.

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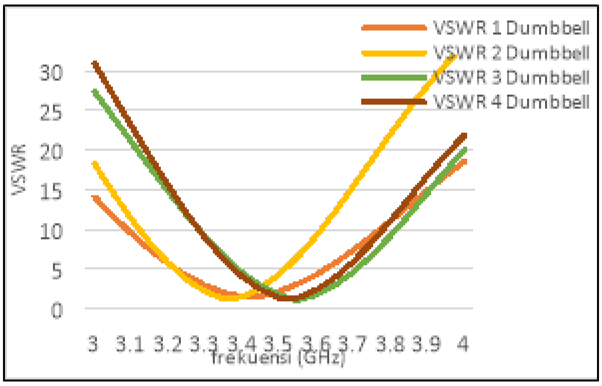

Fig 5. Graph of VSWR from dumbbell shape

The dimension of the DGS that has the lowest operating frequency by using dumbbell shape is tabulated in Table 1. The two dumbbell shapes has four different investigated variables and later are used to calculate the miniaturization of the new antenna dimension. The value of variable a is 9mm, b is 3mm, c is 5mm and d is 2mm.

Table 1

Dimensions of dgs dumbbell shape

Variable	Dimension (mm)
a	9
b	3
c	5
d	2

Every variations of DGS complementary split ring resonator or CSRR dimension both on single and periodic DGS produce the decrement of resonant frequency and has different value of VSWR. Figure 6 is a graph that presents VSWR values from one to four CSRR with vertical arrangement. The dimension of DGS is limited to not exceeding the antenna ground plane.

In Figure 6 it appears that the VSWR value for all design has the same pattern of fluctuation from decreasing then increasing. The design with one CSRR resulting a decrement on resonant frequency down to 3.12 GHz with VSWR value of 2.341 whereas for the design of two CSRRs the resonant frequency is at 3.57 GHz with VSWR value is 1.447. Design with three CSRRs produce the lowest peak of resonant frequency compare to other DGS shapes, it's down to 2.51 GHz with value of VSWR is 1.146 while four CSRRs resulting a resonant frequency down only to 3.59 GHz with VSWR value is 1.02.

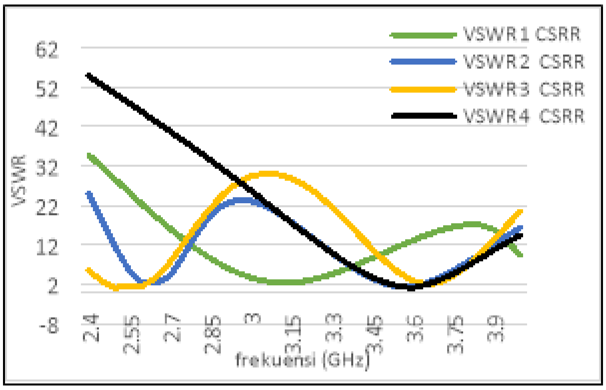

Fig 6. Graph of VSWR from complementary split ring resonator

For complementary split ring resonator that has the lowest operating frequency is tabulated in Table 2. The CSRR also has four different investigated variables and later used to calculate the miniaturization for new antenna dimension. Variable a is 0.2mm, b is 0.1mm, g is 0.5mm and l is 6mm.

Table 2

Dimensions of dgscsrr

Variable	Dimension (mm)
a	0.2
b	0.1
g	0.5
l	6

Same with the previous design, U shape DGS was analysis by varying the dimensions for one until four U shapes and each of them produce different effect to the decrement of the antenna frequency. Figure 7 is a graph that presents a VSWR value from single and periodic U shape DGS with vertical arrangement.

All u shape design has VSWR values below than 2 for each peak of resonant frequency as shown in Figure 7. The design using two U shapes produce the biggest frequency reduction among the other designs. It's reached down to 3.03 GHz with the VSWR value is 1.69. Meanwhile for one U shape

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the resonant frequency still on 3.65 GHz which is same with resonant frequency of the conventional antenna. By using three U shapes it's achieve the operating frequency down to 3.22 GHz and 3.38 GHz for four U shapes.

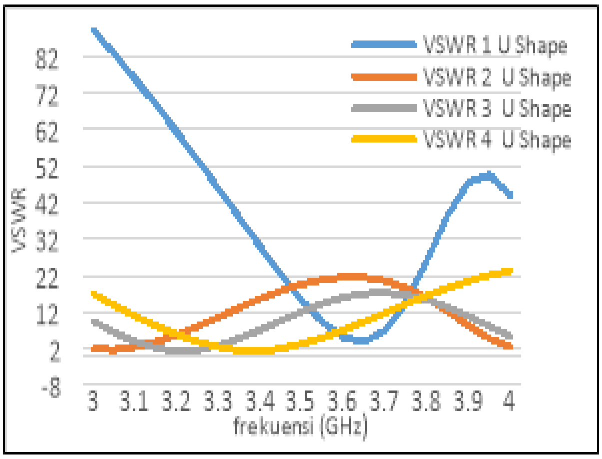

Fig 7. Graph of VSWR from U shape

By using two U shapes it can achieve the lowest operating frequency as tabulated Table 3. U shape DGS has three different investigated variables and later used to calculate the miniaturization for new antenna size. Variable n is 8mm, m is 10mm and g is 1mm.

Table 3

Dimensions of dgs u shape

Variable	Dimension (mm)
n	8
m	10
g	1

Based on the achieved data, lowest operating frequency has been obtained by utilizing two dumbbell shapes, three complementary split ring resonators and two U shapes with dimension of the variable already given on Table 1, Table 2 and Table 3. Through normalization and optimization process, new antenna designs which operate at 3.65 GHz have been obtained. Table 4 lists the parameters DGS antenna with dumbbell, CSRR and U shapes compared to the conventional antenna, all operate at the same resonant frequency of 3.65 GHz.

Table 4

Comparison of the dimension

Variabel	Dimensions (mm)			
	Conventional	Dumbbell	CSRR	U shape
Wp	25.010	23.332	18.080	19.735
Lp	19.136	17.852	13.834	15.101
Ws	34.610	32.288	25.020	27.310
Ls	28.736	26.809	20.774	22.675
Gap	1.530	1.428	1.106	1.207
Yo	5.877	5.483	4.248	4.637
Wfed	3.061	2.856	2.213	2.415

The aperture size of conventional antenna and DGS antenna tabulate in Table 5. For the DGS dumbbell shape, the dimension of antenna aperture is 865.609 so that miniaturization reaches up to 12.965% against the dimensions of conventional antenna. Meanwhile for the CSRR DGS the antenna aperture is 519.765 . It's achieved the miniaturization up to 47.738% which is the biggest reduction compared to the other DGS shapes. Next for the last DGS is U shape which has aperture dimension is 619.254 resulting a miniaturization of 37.735% than the conventional antenna.

Table 5

Comparison of miniaturization

	Aperture dimension (mm^2)	Miniaturization (%)
Conventional	994.553	0
Dumbbell	865.609	12.965
CSRR	519.765	47.738
U shape	619.254	37.735

The conventional antenna can be compared to the antenna with three different DGS shapes in terms of other general parameter of the antenna, such us bandwidth and gain. The simulation result of bandwidth for conventional antenna is 3.13% while for dumbbell shape DGS is 3.62% and for CSRR bandwidth reaches 5.51% while for U shape is 3.84%. It's can be said that the DGS improve

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antenna bandwidth and the widest bandwidth is inherited by CSRR.

For the gain value of the conventional antenna is 3.96 dB while by using DGS it can improve the gain. Dumbbell shape DGS has 6.65 dB which is the highest gain than the other shape meanwhile for CSRR and U shape are 4.23 dB and 4.40 dB respectively.

IV. CONCLUSION

By using defected ground structure method a new dimension of antenna have been obtained with the same resonant frequency at 3.65 GHz. The biggest miniaturization of the antenna with DGS shape is achieved by complementary split ring resonator, U shape and dumbbell shape respectively. The best of VSWR and return loss value at resonant frequency is inherited by DGS complementary split ring resonator. For other antenna parameter such us the widest bandwidth is achieved by using complementary split ring resonator followed by U shape, dumbbell shape respectively and for the highest gain is inherited by dumbbell shape, u shape and complementary split ring resonator respectively.

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