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A HIGH GAIN PIFA AT 2.45 GHZ AND 5.8 GHZ USING WIRELESS POWER TRANSFER TECHNIQUES FOR PACEMAKER APPLICATION

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ABSTRACT

The design of a high gain Planar Inverted F Antenna (PIFA) with two different frequencies for medical pacemaker is presented. Two PIFA designs have been optimized to be operated at ISM band of 2.45 GHz and 5.8 GHz respectively, under tolerable reflection coefficient of less than -10dB. Both of the proposed antennas are developed from copper plate with a simple structure of rectangular patch. All design and simulation has been carried out using Computer Simulation Technology (CST) Microwave Studio Suite. The simulated and measured results of the fabricated antenna on reflection coefficient, bandwidth radiation pattern, and gain are presented to validate the usefulness of the presented design. The 2D Anechoic Chamber and Agilent Technologies Network Analyzer have been used for the measurement. Both 2.45 GHz and 5.8 GHz antennas have successfully manage to achieve high gain of 6dB and 8.2dB respectively with a directional beam pattern. The presented ISM PIFAs could be potential for point-to-point communication using wireless power transfer technique for medical pacemaker application.

Keywords: PIFA antenna, pacemaker antenna, medical application and implanted.

INTRODUCTION

In the early stage, The Medical Implant Communication Service (MICS) has been doing some research and proceed with the proficiency of pacemaker for heart surgery. Pacemaker is a device that placed in the chest or abdomen and function to control abnormal heart rhythms. The MICS system can operate wirelessly to check the rhythm of the cardiac heartbeat and collect information from an antenna that implanted in the human body without piercing wire in the skin [1]. This implanted medical device has the capability to communicate with the data based on external programmer known as radio-frequency telemetry link. Such Telemetry System operates radio frequency to enable bidirectional communication [2]. This pacemaker has two parts, transmitter and receiver with a high directional gain antenna antenna is required to ensure the communication reliability. Figure-1 show the pacemaker antenna placed in the chest of a human body.

Normally the most usable transmitter is Planar Inverted-F Antenna (PIFA) (short patched) for wireless power transmission (WPT). Pacemaker uses battery which could not sustain for long time. Besides that, an operation is needed to replace the pacemaker battery from the body. Apart from that it causes trauma or harm to the human body. Therefore, a PIFA for pacemaker is proposed to charge the battery wirelessly using WPT technique which is more beneficial to the user. However, designing a high gain antenna is challenging with few consideration of achieving good antenna performance with a compact size.

Previous research has been discussed the usable of PIFA for MCIS band in [3, 4]. Paper [3] designed PIFA at 400 MHz with a perfect dimension of 40X30X10mm3. The PIFA is positioned on the top of the substrate and pacemaker [3]. The antenna radiating elements is ensured to match 50 ohms in the human body tissue. Uisheon and Kim Jaehoon Choi have embedded antenna with pacemaker in pig tissue which resulted to S11 value of -10.94 dB at 403MHz [4]. The PIFA has peak gain and radiation efficiency of -20.19dB equal to 1.12% respectively. The MICS pacemaker transmits important information from the implanted antenna in the body to the external equipment through wireless communication links which minimizes the required time for data extraction.

In this research, two transmitters of PIFA operating at 2.45 GHz and 5.8 GHz resonant frequencies are design and compared in terms of the advantages and disadvantages for pacemaker application in simulation and measurement wise. Both antennas are developed using a full copper plate with a rectangular shape of radiator. Such antennas have high gain of more than 6dBi with a directional beam pattern. The proposed antenna has performed well under reflection coefficient of more than -10dB which represent 90% of power transmission and 10% of power reflected. The antennas have compact size with a ground plane size for 2.45 GHz antenna is 40 x 50 mm^2 while for 5.8 GHz, the antenna ground depicted as 60 x 70 mm^2.

This letter is organized as follows. Section 2 conversed on the development of the antenna design for 2.45 GHz and 5.8 GHz. Moreover, the fabricated antenna is presented as well in this section. All verification of the antenna performances of reflection coefficient, gain, radiation pattern and efficiency is discussed in Section 3. Finally, conclusion is drawn in Section 4.

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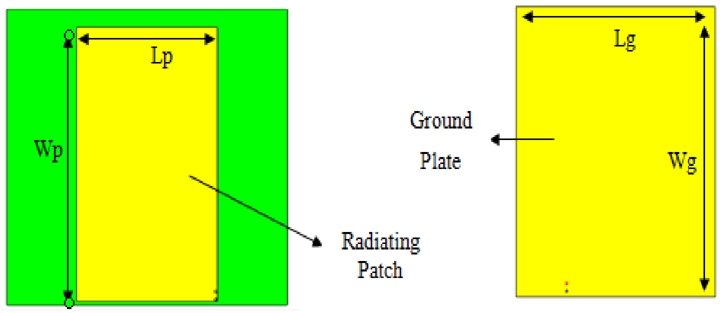
ANTENNA DESIGN AND CONFIGURATION

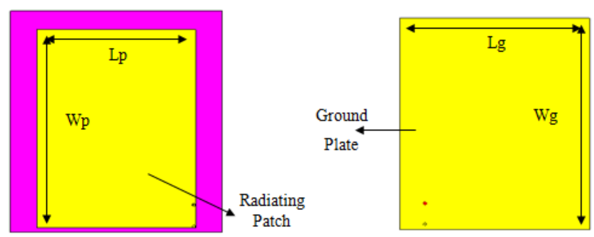
The proposed antenna in this work is targeted to be operable for ISM implantable application. The radiating patch element for frequency of 2.45 GHz and 5.8 GHz has dimensions of Lp × Wp and the ground plane dimensions is Lg × Wg. The material that is used for radiating patch and ground plane material is a lossy copper (annealed). The radiating element sits on top of an air gap and having a thickness *t* = 3mm for 2.45GHz whereas 2mm for 5.8GHz. The space between the radiating patch and the ground plane is filled with an air gap. Shorting pin is a cylindrical shape positioned between the ground plane and the radiating patch.



(a) (b)

Figure-1. PIFA geometry at 2.45GHz (a) Front view, and (b) Back view

Feeding point is a cylindrical shape and it is connected between the radiating patch and half dimension of the air gap to connect the feed port through ground plane. Both shorting pin and feeding point use copper (annealed) material and the type is lossy metal. The port for feeding point is a discrete port. The antenna is fed with a single coaxial cable with an appropriate 50 Ω matching point. Figure-1 and Figure-2 show the PIFA geometry for 2.45 GHz and 5.8 GHz respectively. Besides that, Table-1 summarized the dimension of the proposed antenna.



(a) (b)

Figure-2. PIFA geometry at 5.8 GHz (a) Front view, and (b) Back view.

Table-1. Experimental results of uniform random-3-SAT benchmark instances.

Frequencies (GHz)	**2.45**	**5.8**	**2.45**	**5.8**
Parameters	**Length** (mm)		**Width** (mm)	
Gound Plane	60	40	70	50
Patch	30	30	64.7	44.8
Feeding Point	3.25	6.2	14.7	14.7
Shorting Pin	1.35	1.3	14.7	14.7
Air Gap	60	40	70	50
	Para	Radius (mm)	Height (mm)	
Gound Plane	-	-	0.035	0.035
Patch	-	-	0.035	0.035
Feeding Point	0.3	0.3	3	2
Shorting Pin	0.3	0.3	3	2
Air Gap	-	-	3	2

The PIFA antenna that operates at resonant frequency of 2.45 GHz and 5.8 GHz are selected. The design consists of ground plane, feeding point, shorting pin, air gap and radiating patch. The antenna is fed with single coaxial cable with 50 Ω impedance matching point.

After few optimization routine, the proposed antenna is fabricated and soldered with an SMA connector

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as shown in Figure-3. Both antennas are fabricated with copper plate for ground and radiator according to the dimensions. Both has air gap between ground plate and radiator plate. The SMA connector is soldered to coaxial feed line for both antennas. SMA connector is soldered to the 50Ω transmission line to allow connection through the antenna. Besides that, there are shorting pin between the ground plate and radiator plate. Finally, after fabrication can be tested in Network Analyzer to analyze all the parameters.

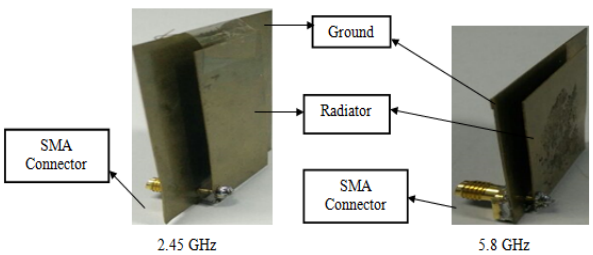

Figure-3. Fabricated PIFA antenna for 2.45 and 5.8 GHz.

RESULTS AND DISCUSSIONS

The goal of the design antenna is to achieve S11 of less than -10 dB where 90% of power transmitted and 10% of power reflected. To validate this concept, the experimental antenna measurement is focused on the reflection coefficient result that performs using PNA in the research cluster lab of School Computer and Communication Engineering UniMAP. Initially, comparison of two antennas which developed with two different frequencies is studied. Besides that, the antenna performances in terms of all parameters are discussed.

Figure-4 shows the reflection coefficient of 2.45 GHz at a different width of the patch. It is observed in Figure-6 that as the width of the patch is increased, the frequency is shifted to left and reflection coefficient is shifted down. When the width of the patch is decreased from 64.9 mm to 64.7 mm the reflection coefficient is shifted down to -27.259 dB which is a perfect reflection coefficient with at particular needed frequency.

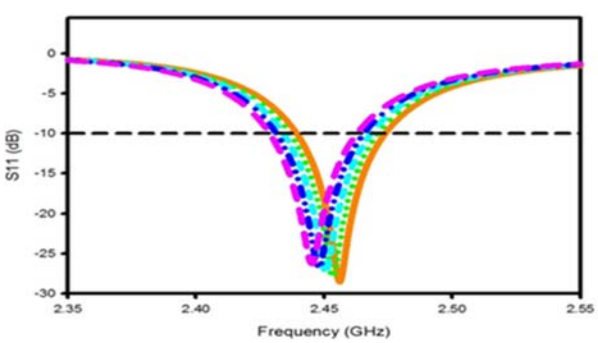

Figure-4. Reflection coefficient of 2.45 GHz PIFA at different width of patch.

Figure-5 above shows the reflection coefficient of 2.45 GHz at a different length of the patch. There are differences between lowest and highest length value of the patch. The frequency is shifted to left if the length of patch increased. At the same time, the reflection coefficient is shifted to down to get a lower value than -10 dB. The most perfect reflection coefficient is -27.259 dB due to the desired frequency of 2.45 GHz and that particular length, which is 30 mm after parameterized, is used in this design simulation.

Figure-6 above shows the reflection coefficient of 5.8 GHz at a different width of the patch. As the width of the

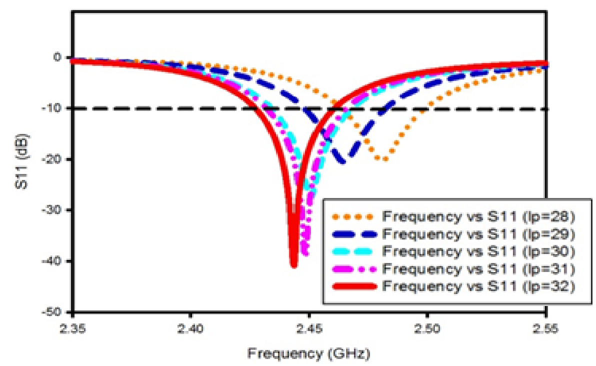

Figure-5. Reflection coefficient of 2.45 GHz PIFA at different length of patch.

patch is increased, the frequency is shifted to left and reflection coefficient is shifted up. When the width of the patch is decreased from 45 mm to 44.8 mm the reflection coefficient is shifted down to -19.471 dB which is a perfect reflection coefficient with a suitable frequency which is 5.8 GHz. So, if the width of patch is increase, then the reflection coefficient is shifted up whereas the frequency is shifted down.

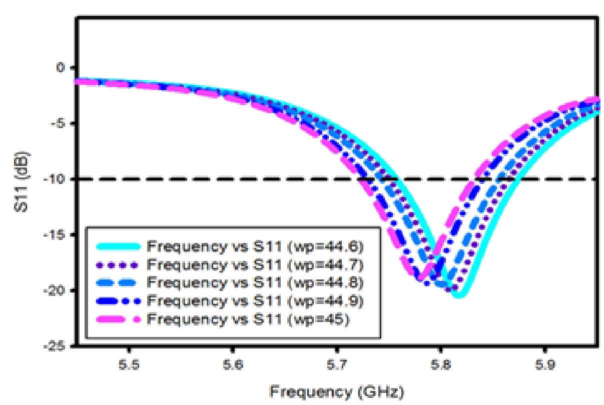

Figure-6. Reflection coefficient of 5.8 GHz PIFA at different width of patch.

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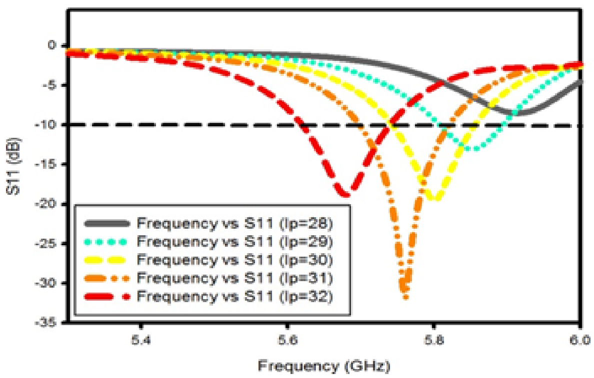

Figure-7. Reflection coefficient of 5.8 GHz PIFA at different length of patch.

Figure-7 shows the reflection coefficient of 5.8 GHz at a different length of the patch. The frequency is shifted to left if the length of patch increased. At the same time, the reflection coefficient is shifted down to get a lower value than -10dB. When the length of patch is set to 31 mm from 30 mm, reflection coefficient dramatically decreases from -19.471 dB to -31.751 dB and increase back to -18.87 dB when the length is set to 32 mm. The most perfect return loss is -19.471 dB due to the desired frequency of 5.8 GHz and that particular length, which is 30 mm after parameterized, is used in this design simulation.

Reflection coefficient measurement

Figure-8 and Figure-9 have compared the simulated and measured reflection coefficient of both antennas of 2.45 GHz and 5.8 GHz. For the first antenna there is slightly different between simulation and measurement result which is 2.45 GHz from simulation and 2.435 GHz for measurement. Besides, the second antenna shows frequency shifted to the left which gives 5.77 GHz for measurement and 5.8 GHz for the simulation.

The measurement is differing from simulation results due to some technical errors during fabrication. This is due to the errors such as inexact antenna fabrication that could cause by environmental factors in measured result during antenna testing stage. Besides that, mesh cells of an antenna also causes slightly different between simulation and measurement. During simulation a part of the antenna covers with mesh cells but when comes to fabrication there is no mesh cells and we will use the whole dimension of the antenna. The oxidation of the copper (patch and ground element) of the antenna also affects the result. In order to avoid this happen, the antenna must be carefully handle and cover to keep away from contact with human skin. Therefore, the measurement should be tested in chamber room so that no interference with others signals. This action will lead to quality improvement of the measurement result.

Radiation pattern measurement

The radiation pattern in 3 dimensional views of 2.45 GHz and 5.8 GHz respectively. The 2.45 GHz has high directivity of 6.818 dBi and gain of 6.401 dB. This shows that the proposed antenna has high efficiency of more than 85%. The radiation pattern of 5.8 GHz with a high gain of 8.61 dB and achieves 8.766 dBi of the directivity. The 2.45 GHz antenna has an omnidirectional pattern towards the z-axis. While the 5.8 GHz antenna has a diversify beam pattern.

The radiation pattern measures the capability of an antenna to receive or transmit in a certain direction. It is usually represented graphically for the far-field conditions in either horizontal or vertical plane. It also gives a measure of the gain and directivity. The gain is assumed to mean directional gain of the antenna compared to an isotropic radiator transmitting to or receiving from all

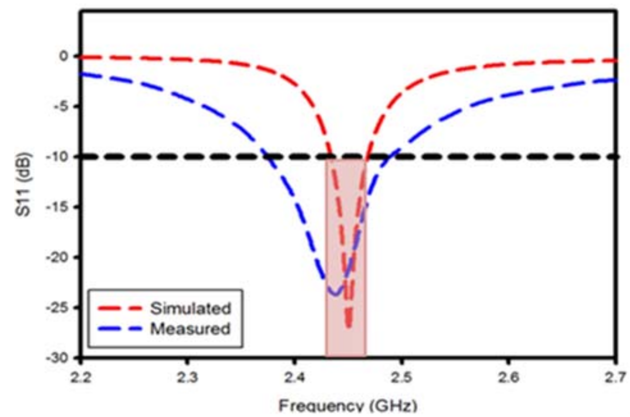

Figure-8. Reflection coefficient of PIFA at 2.45 GHz.

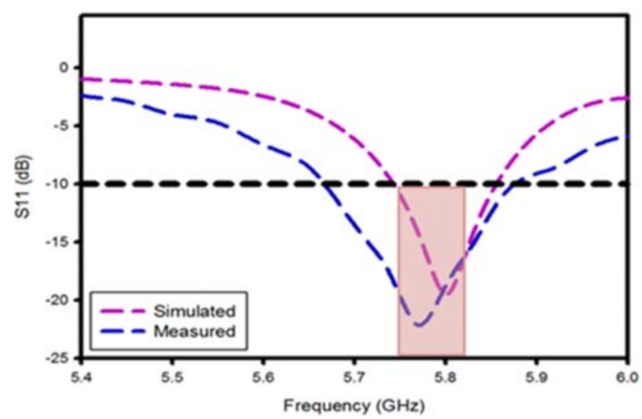

Figure-9. Reflection coefficient of PIFA at 5.8 GHz.

directions. Figure-10 shows the measured radiation pattern for 2.45 GHz antenna in terms of E-co, E-cross plane; H-co and H-cross plane whereas Figure-11 shows the measured radiation pattern for 5.8 GHz antenna in terms of E-co, E-cross plane, H-co and H-cross plane. Theoretically, this radiation pattern of E-co and H-co will determine the polarization in terms of larger size. Based

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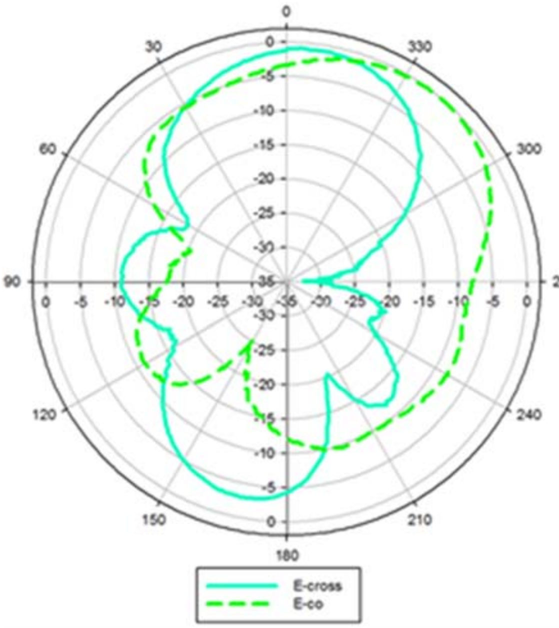
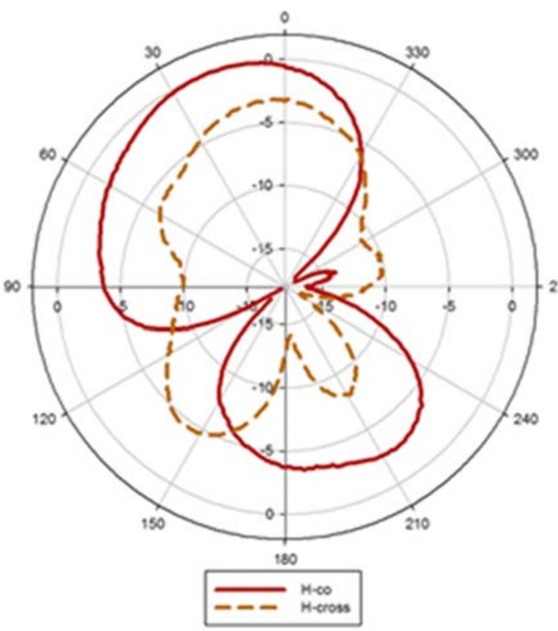
on Figure 10 and 11, the E-co and H-co will be larger than E-cross and H-cross.

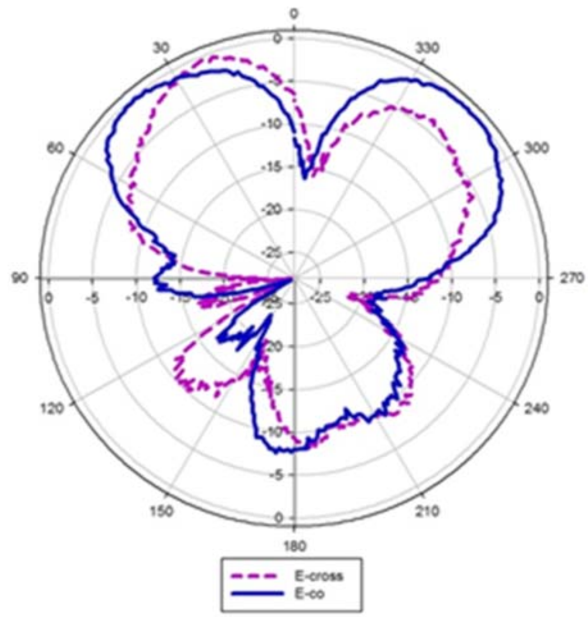


(a)

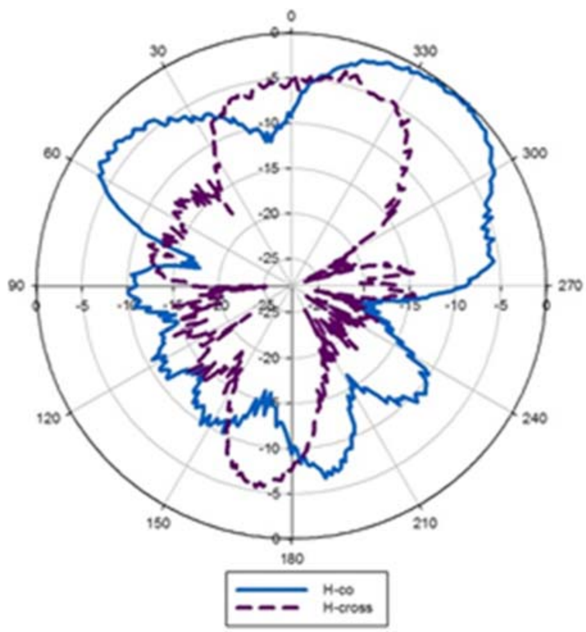


(b)

Figure-10. Measured radiation pattern of PIFA at 2.45 GHz. (a) E-co and E-cross, and (b) H-co and H-cross.



(a)



(b)

Figure-11. Measured radiation pattern of PIFA at 5.8 GHz. (a) E-co and E-cross, and (b) H-co and H-cross.

CONCLUSIONS

A comparison study has been made for both PIFA antennas. The results show that PIFA antenna which operates at the frequency of 5.8GHz has smallest dimension which is more suitable to be implanted into human body. The dimension of the antenna gets bigger as the frequency reduces. The propagation gain increases as the operating frequency increase. PIFA shows a huge difference in the increment of gain. At lower frequency, PIFA has Omni directional radiation pattern. PIFA's

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radiation pattern changes to directional pattern as the frequency increases. PIFA antenna has smaller dimension at the frequency of 5.8 GHz; it is not suitable to be implanted into human body rather than 2.45 GHz antenna. The radiation of the antenna increases as the frequency increase. The tissues and muscles might get damaged since the signal from the implanted antenna penetrates through the human body. The PIFA which operates at 433

MHz can be used as implanted antenna since it has less radiation effect, low power and Omni directional radiation pattern. The PIFA antenna which operates at 433 MHz is not recommended to be used as implanted antenna as it has very large dimension.

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