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Compact Circularly Spiral Planar Inverted-F Antenna for Medical Implant Application

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***Abstract*—A combination technique to reduce the physical dimension of device to be more compact is proposed in this paper to design an antenna for medical implant application. Two design techniques, i.e. planar inverted-F and geometry modification, are combined and implemented to construct a compact circularly spiral planar inverted-F antenna (PIFA) to operate around frequency of 920MHz. The antenna is deployed on an FR4 Epoxy dielectric substrate with the thickness of 0.8mm. Before the hardware realization, the parameters of antenna including reflection coefficient, voltage standing wave ratio (VSWR), gain, and radiation pattern as well as its physical dimension are investigated numerically to obtain the optimum performance design. From experimental characterization, it shows that the realized antenna in circular shape which has the diameter of 18mm resonates at frequency of 911MHz with measured bandwidth and gain of 20MHz and -29.82dBi, respectively.**

***Keywords*—compact circular shape; geometry modification; medical implant application; spiral planar inverted-F antenna**

I. Introduction

The challenge of designing antenna for implanted devices mainly comes from the dimensioning of the antenna itself. One of requirements for implanted devices is that the antenna should be small enough so it will safe and not damages any part of body, while keeping its performances sufficient enough for the requirement of system. For this purpose, a microstrip patch antenna has been one of solutions to be considered for the application due to small dimension, light weight, low profile, easy and cheap fabrication [1]– [4]. Among the advantages of microstrip patch antenna, however, its physical dimension cannot be made any shorter than half wavelength at the desired operating frequency, since the antenna only resonates at the patch length of the order of half wavelength. Therefore, various techniques emphasized for reducing its physical dimension have been proposed and developed intensively in recent years.

One of techniques to reduce the physical dimension of microstrip patch antenna is by introducing a shorting pin that connects the patch of antenna with the groundplane. This techniques allows the antenna to resonate at larger wavelength or smaller frequency. This particular antenna is called planar inverted-F antenna (PIFA). Theoretically, a PIFA can resonate at a quarter wavelength, so it will reduce the length of antenna patch into the half of a regular microstrip patch antenna. Another technique to reduced the physical dimension of microstrip patch antenna is by geometry modification. The most basic geometry of a microstrip patch antenna which is usually used for implementation is rectangular or circular patch.

As is well-known, the dimension of patch is determined the operating frequency of the antenna [1], the longer or larger the patch, the lower the operating frequency will be. However, for antennas with relatively low operating frequency such as MICS, ISM 915MHz, and Indonesian RFID band [5]– [7], it is found that the physical dimension of antenna is still too large to be practically implemented as an implanted antenna. Therefore, the geometry modification of patch antenna by deforming it into spiral shape or meander line will increases the length of patch antenna occupies a given area. This means it is not necessary to increase the size of dielectric substrate to accommodate larger patch for lower frequencies. It should be noted that a patch in meander line or spiral shape can acts as a lumped inductor, so it has different characteristics from a regular rectangular or circular patch [8]. In addition, meander line or spiral shape is also affected by the parasitic capacitance that comes from the gaps between the turns.

In connection to reduce the physical dimension, in this paper, a compact circularly spiral planar inverted-F antenna (PIFA) is proposed to be construct by combining the design technique of planar inverted-F and geometry modification. The antenna which is intended to operate at 920MHz for medical implant application is designed to be deployed on an FR4 Epoxy dielectric substrate with the thickness of 0.8mm. The basic parameters including reflection coefficient, VSWR, gain and radiation pattern are used for performance indicators both in the design and realization. Moreover, the experimental characterization results for each parameter will be compared to the design results to evaluate the performance of realized proposed antenna.

II. Circularly Spiral PIFA Design

In the design process, the requirements are determined form the existing link budget calculation [9]. The antenna with minimum gain of -30.86dBi is required for enabling communication between the implanted device and the external receiver. Whilst the operating frequency of antenna is at frequency of 920MHz based on Indonesian RFID band [7]. Fig. 1 illustrates the final construction of proposed compact PIFA with circularly spiral microstrip patch on an FR4 Epoxy dielectric substrate with the thickness of 0.8mm. Some parametrical studies are conducted carefully to obtain the final dimension of proposed antenna to optimize the performance of antenna. The diameter of circular shape substrate dielectric

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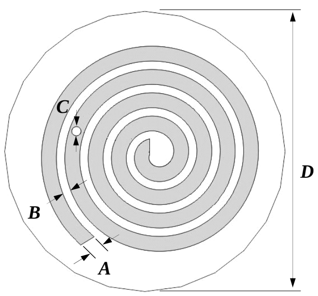


Fig. 1. Construction of compact circularly spiral planar inverted-F antenna

is 18mm. Whereas the total length of microstrip patch made of metal copper which give the resonant frequency of 920MHz is 104mm with the shorting pin located at 58mm along the microstrip patch from the feed point.

The width of microstrip patch and the separation of patch in the turns and 1mm and 0.5mm, respectively. The wider separation of patch affects the larger diameter of dielectric substrate, this also applies for patch width. The thickness of microstrip patch on top side of dielectric substrate as well as the groundplane on the bottom side is 0.035mm. To feed the antenna, an SMA connector is connected to the feed point form bottom side of dielectric substrate. Whilst to obtain an accurate analysis, the copper conductive loss of patch and groundplane as well as the substrate dielectric loss are accounted for. The detail dimension of proposed compact circularly spiral planar inverted-F antenna is listed in Table I.

TABLE I. DIMENSION OF COMPACT CIRCULARLY SPIRAL PLANAR INVERTED-F ANTENNA

Parameter	Dimension (mm)
A	1.0
B	0.5
C	0.6
D	18.0

III. CHARACTERIZATION AND DISCUSSION

After obtained the optimum numerical design, the proposed compact circularly spiral PIFA is then realization through wet etching technique. Fig. 2 shows the pictures of realized antenna

Fig. 2. Picture of realized compact circularly spiral planar inverted-F antenna

on an FR4- Epoxy dielectric substrate as prescribed in the design. Two identical antennas are realized to be measured and compared each other. To obtain the characteristics of realized antenna, the parameters are experimentally characterized where the measured results will be verified and compared to the simulated results.

Figs. 3 and 4 plot the measured results of reflection coefficient and VSWR for realized antenna, respectively, with the simulated results are depicted together for comparison. From both figures, it shows that the operating frequency of both realized antennas shifted to the lower frequency around 9MHz. The simulated operating frequency is 920MHz as specified in the requirement, while the measured operating frequency is 911MHz for both realized antennas. The discrepancies in operating frequencies is probably evoked by the different value of relative permittivity of dielectric substrate set in the simulation and used in the realization. It seems that the relative permittivity value of dielectric substrate used in the realization is higher than of the dielectric substrate set in the simulation. As the relative permittivity higher, the operating frequency changes to be lower and vise versa.

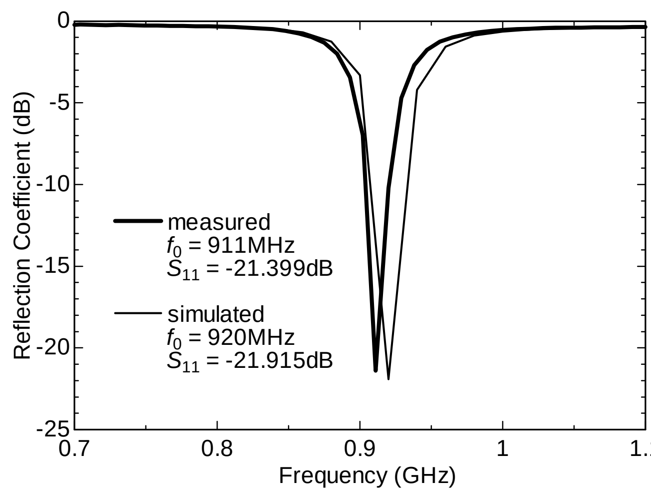


Fig. 3. Measured and simulated reflection coefficient of proposed planar inverted-F antenna

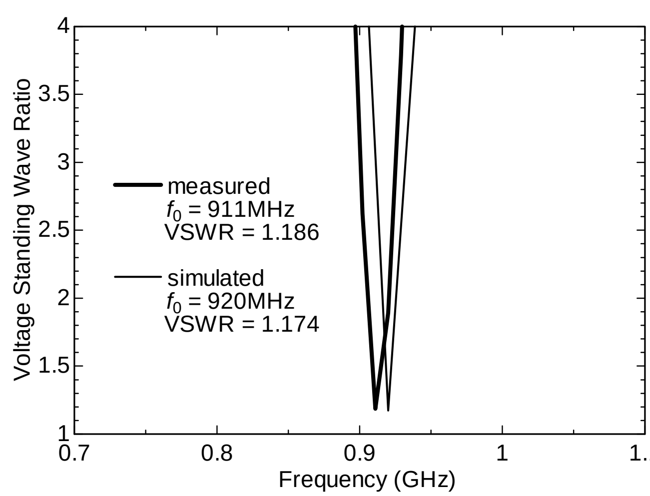


Fig. 4. Measured and simulated VSWR of proposed planar inverted-F antenna

Due to the small size aperture and dimension of antenna, the gain of proposed antenna is very small. This can be seen in the measured and simulated gains depicted in Fig. 5. The different value between measured and simulated gain is probably affected by the different value of copper conductive loss and substrate dielectric loss set in the simulation and used in the realization. From the results, it is noticeable that the losses used in the realization are higher than the losses set in the simulation, as a result the radiated power of realized antenna decreases. However, both results show similar tendency for all frequency ranges, even in some frequencies both results shows the same value of gain.

Fig. 6 depicts the measured results of radiation pattern for realized antenna, respectively, with the simulated results are plotted together for comparison. The results show that the proposed antenna has the wide beamwidth of H-plane radiation pattern with the radiated angle at 130°, whilst the E-plane radiated plane is radiated into 2 different directions due to the spiral shape of patch antenna. It should be noted that the measured results both for H-plane and E-plane show a good agreement qualitatively with the simulated results. In overall, the comparison of experimental and numerical characterization is summarized in Table II which indicate the compliance of realized compact circularly spiral PIFA to the numerical design with some acceptable discrepancies.

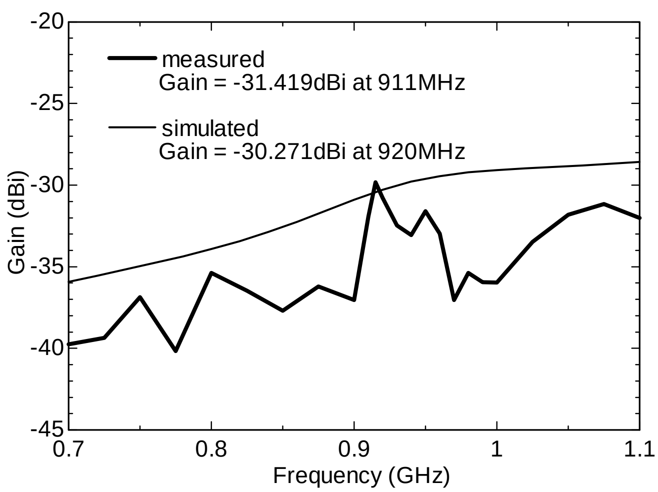


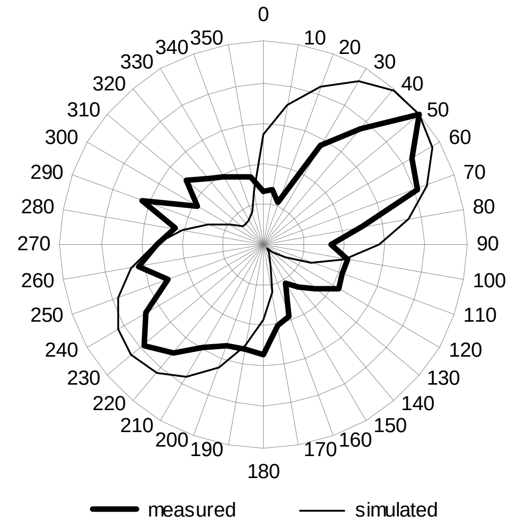
Fig. 5. Measured and simulated gain of proposed planar inverted-F antenna

TABLE II. SUMMARY OF MEASURED AND SIMULATED RESULTS

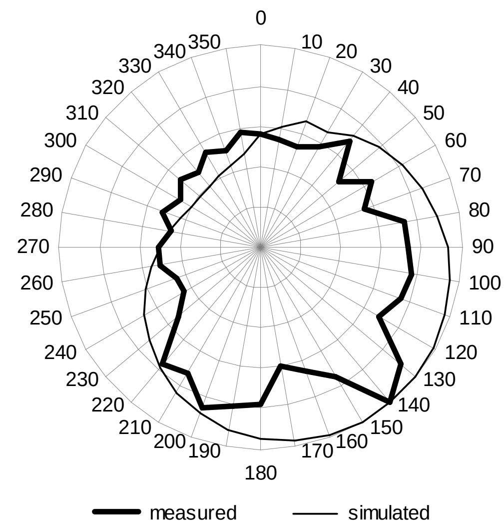
Parameter	Measured	Simulated
Operating frequency	911MHz	920MHz
Minimum reflection coefficient	-21.399dB	-21.915dB
Gain at 920MHz	-30.785dBi	-30.271dBi
-10dB working bandwidth (f_{BW})	20MHz (2.195%)	24.3MHz (2.641%)

IV. CONCLUSION

A planar inverted-F antenna (PIFA) in circularly shape for medical implant application has been numerically designed and experimentally characterized. A combination design technique, i.e. planar inverted-F and geometry modification has been successfully implemented to reduce the antenna dimension in producing a compact circularly spiral PIFA to operate around frequency of 920MHz. The antenna that has had diameter of 18mm was deployed on FR-4 Epoxy dielectric substrate with the thickness of 0.8mm. From numerical characterization, the proposed antenna has had operating frequency of 920MHz with bandwidth and gain of 24.3MHz and -30.271dBi, respectively. Whilst from experimental characterization, it has been demonstrated that the realized antenna has resonated at frequency of 911MHz with measured bandwidth of 20MHz and measured gain of -30.785dBi. From the results of numerical and experimental characterizations, although there was a slight different in some parameters, however it has been shown that the characteristics of realized antenna have good agreements qualitatively with the design one. In addition, the improvement to reduce the physical dimension of antenna with different shape is still being investigated where the result will be reported in the near future.



(a) H-plane



(b) E-plane

Fig. 6. Measured and simulated radiation patterns of proposed planar inverted-F antenna

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