Inset Feed for Antenna Miniaturisation

Mazlina Esa, Suhaila Subahir, Norul Husna Ahmad and Sharifah Kamilah Yusof
Jabatan Kejuruteraan Perhubungan Radio, Fakulti Kejuruteraan Elektrik,
Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor DT, Malaysia
e-mail: mazlina@suria.fke.utm.my

Abstract- **An experimental investigation of a rectangular microstrip patch structure having an inset or recessed feed at its non-radiating edge is presented. The basic structure operates at 1.6 GHz, when fed with a coaxial line or microstrip side feed line. However, the inset fed structure operates at a lower frequency of 1.35 GHz. The antenna does not need any impedance matching network. The well-matched antenna exhibits similar performance to that of the basic structure. The inset feed structure behaves like a matching line as well as miniaturising the physical antenna structure.**

Keywords:
Inset feed, miniaturisation.

I. INTRODUCTION

Most of the radiating elements of single operation microstrip antennas are on one side of a dielectric substrate. The presence of its feed line can be on the same layer or underneath the substrate. This paper investigates experimentally the effect of an inset or recessed feed line structure to the operating frequency of a basic rectangular microstrip patch antenna [1]. The feeding line was chosen to be at the centreline of the non-radiating edge of the antenna radiating structure. A similar basic structure operating at a frequency of 1.6 GHz and having a coaxial cable feed is also presented for comparison purposes. The basic structure has been numerically simulated using an electromagnetic software. Both antennas have been built and experimentally tested.

II. ANTENNA DESIGNS AND NUMERICAL SIMULATION

The basic structure of the rectangular patch (RPC) antenna is illustrated in figure 1. The dimensions of the antenna are initially determined using the mathematical formulations available in the literature [1], [2], [3]. The chosen microwave laminate has the following specifications: relative permittivity ε_r = 2.95, thickness of substrate h = 1.57 mm, loss tangent tan δ = 0.0028, thickness of copper t = 35 μm, surface roughness = 0.0024 and conductivity of copper σ = 5.882 x 10^7 S/m. For an operating frequency of 1.6 GHz, the dimensions of the width and length are 54 mm and 67 mm, respectively. The width is broader for perfect match.

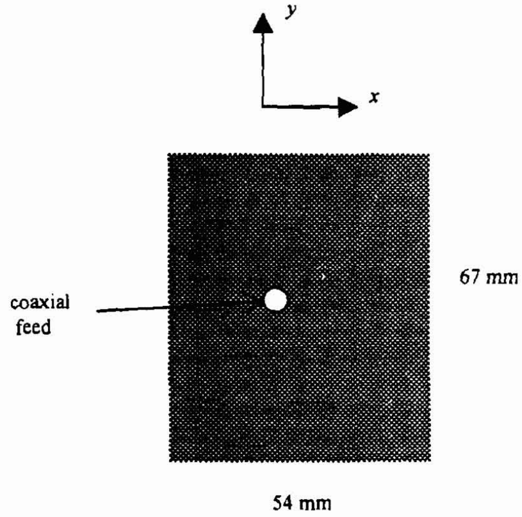

Figure 1. Basic rectangular structure.

The location of the 50 ohm coaxial cable feeding point was determined using the Micropatch 2.0 electromagnetic simulation software [4], together with the optimum size of the patch operating at the specified frequency. The location was found to be 17 mm from the left edge along the centreline of the antenna width. The coaxial feed is directly connected from underneath the dielectric through a via. The via is merely sufficient to allow the center pin of the connector at the input to pass through. The optimised size of the patch which was numerically simulated by Micropatch agrees well with that mathematically formulated. The command RPDESIGN was used for the optimisation process. The input parameters required by the software are dielectric constant, loss tangent, height of substrate, thickness of conductor, conductivity of conductor and surface roughness. The results of the optimisation is given in Appendix 1.

The input of the inset feed line with inset depth dimensions of r_w and r_h is chosen to be at the centre of the non-radiating edge. A 50 ohm microstrip line is designed to ease impedance match at the input, assuming that the location of minimum reflection coefficient exists. The inset feed antenna (RPI) is illustrated in figure 2. The width of the feed line, w_f, was calculated as 3.96 mm using the mathematical formulations available in the literature [5].

This was later verified using the TLDESIGN command available in the Micropatch 2.0 software. The board size was chosen to be of similar shape with a gap of 10 mm existing all around the radiating surface. The dimensions do not exceed half-wavelength. Larger dimensions are expected to degrade the performance of the antenna. However, performance of the antennas in terms of board size has not been investigated in this work.

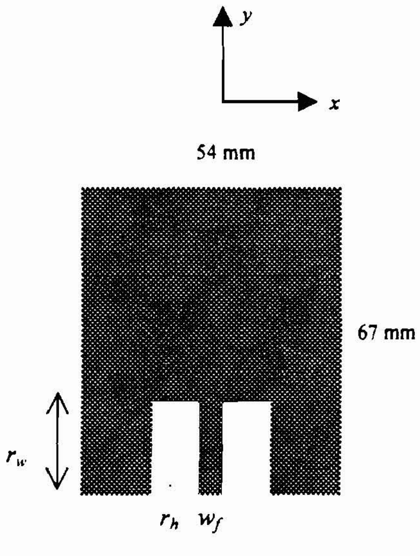

Figure 2. Inset feed structure.

III. HARDWARE REALISATION AND EXPERIMENTS

The antennas were implemented on the chosen microwave laminate using the standard photolithography and wet etching techniques for printed circuit boards. In order to directly match with the connectors of the measurement set-up, a 50 ohm SMB connector is soldered at the input of each antenna. For each type of antenna, two identical antennas have been fabricated. This serves the purpose of having identical transmitting and receiving antenna which will simplify the calculation of antenna gain as proposed in [6].

Single and two port measurements were performed with the Feedback Antennalab measurement set-up. The antennas were tested in the co-polarisation E-plane, co-polarisation H-plane, cross-polarisation E-plane and cross-polarisation H-plane alignments [7]. The distance between the transmitting and receiving antennas is in the Fraunhofer far-field region [6]. The separation chosen was 1 m. However, this paper is focussed on the detailed discussion of the single port measurement results only.

IV. RESULTS AND DISCUSSION

Numerical simulation of the basic coaxially fed rectangular patch (RPC) is performed using Micropatch 2.0 RPDESIGN command. The command RPANALYZE is then used to simulate the single and two-port performances of the antenna. A very low return loss of –56 dB as shown in figure 3 is obtained at the operating frequency of 1.6 GHz, indicating an almost perfectly matched antenna at the input. This corresponds to an almost perfect voltage standing wave ratio (VSWR) of 1.00325 and an input impedance of 49.8447 ohm. The –10 dB reflection bandwidth was found to be 30 MHz or 1.875 %. Such narrow bandwidth will be a disadvantage in application s where wide bandwidth is required. The basic patch possesses a high efficiency of 71 % and 6.51 dBi directivity. This corresponds to a gain of about 4.62 dBi [6]. The antenna possesses a broadside radiation pattern.

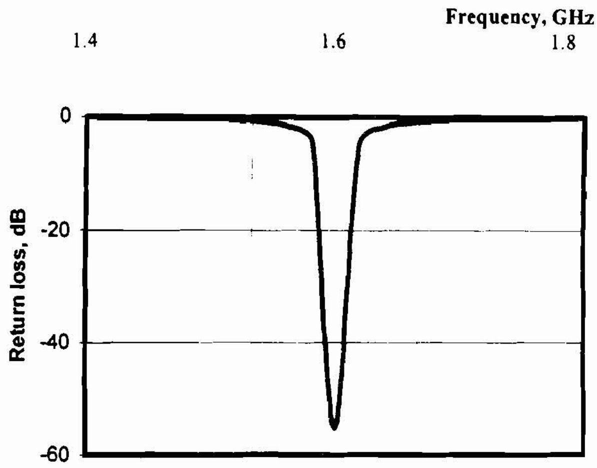

Figure 3. Simulated return loss of the RPC antenna.

Measured results of the RPC antenna showed reasonably well matched performance at the corresponding 1.58 GHz operating frequency, indicating low return loss (figure 4).

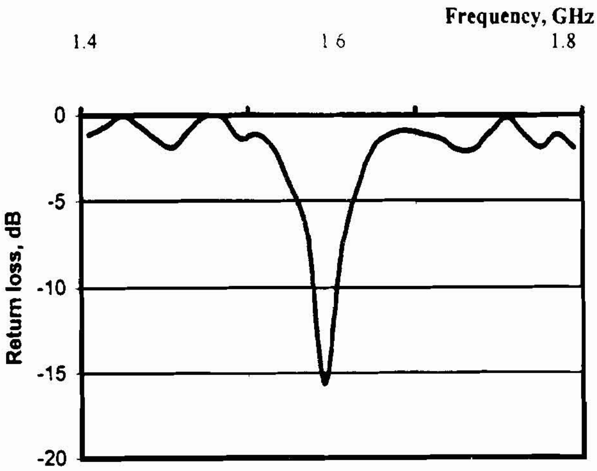

Figure 4. Measured return loss of the RPC antenna.

The –10 dB reflection bandwidth (2:1 VSWR) is 22 MHz or 1.375 %. A very slight difference in the measured frequency of operation and less well-matched impedance are probably due to experimental errors caused by fabrication tolerances and connector soldering. The slight difference will not significantly degrade the performance of the antenna.

The Micropatch software is limited to the simulation of basic patch structures. Hence, the inset fed antenna has been fully investigated through experiments. Without any inset depth made into the antenna, no resonance is observed as depicted in figure 5.

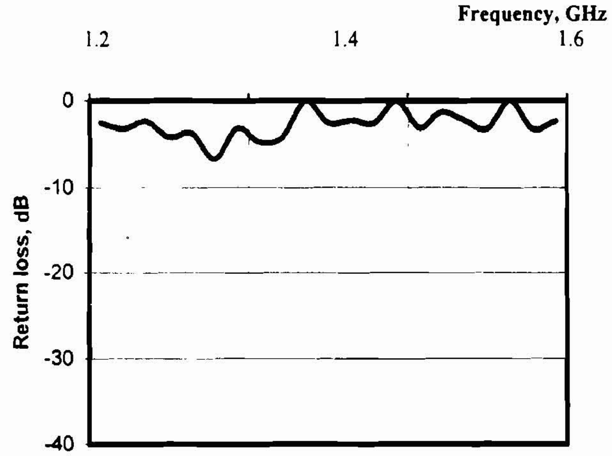

Figure 5. Measured return loss of the RPI antenna, without any inset depth.

An inset depth of increasing sizes is then introduced into the antenna. An example of a measured return loss with an inset depth of r_w = 3 mm and r_h = 6 mm is shown in figure 6.

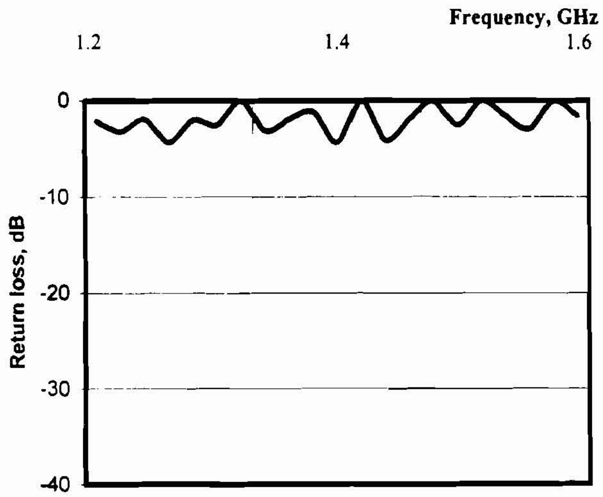

Figure 6. Measured return loss of the RPI antenna with an inset depth of r_w = 3 mm and r_h = 6 mm.

After successive depth sizes, a perfect impedance match is finally achieved. The dimensions of the inset depth are r_w = 22 mm and r_h = 9 mm. The antenna resonates at the frequency of operation of 1.35 GHz. At this frequency, the return loss is −35 dB as depicted in figure 7. There is a shifting of 230 MHz less from the measured coaxially fed basic rectangular structure. This corresponds to a value of almost 15 % difference. A coaxially fed structure having the same frequency of operation will have the a broader width dimension of 79 mm [1, [2], [3]. This corresponds to a factor of 1.5 increase in the size of the antenna.

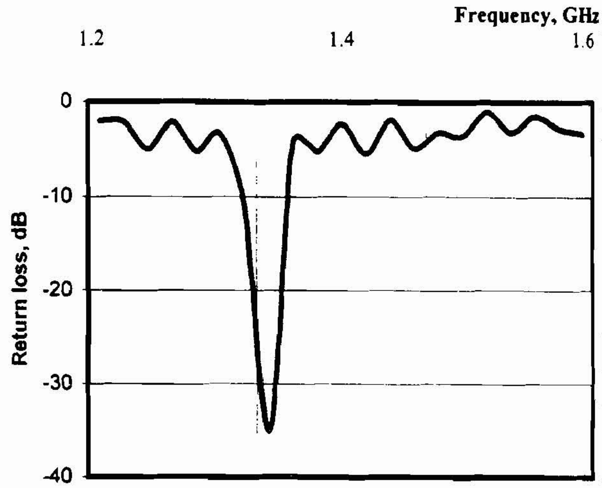

Figure 7. Measured return loss of the RPI antenna with an inset depth of r_w = 22 mm and r_h = 9 mm.

Further inset depth introduced will only worsen the impedance match. This can be observed from the return loss response as shown in figures 8 and 9 for an additional 1mm and 2 mm sizes of r_w, respectively. The corresponding measured return losses are −33.5 dB and 17 dB, respectively.

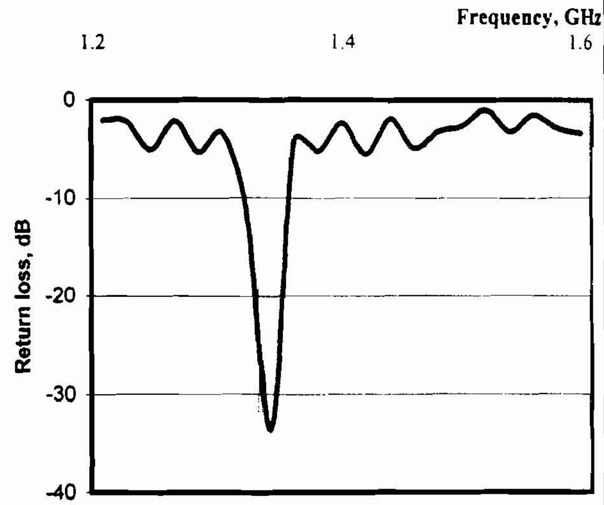

Figure 8. Measured return loss of the RPI antenna with an inset depth of r_w = 23 mm and r_h = 9 mm.

Frequency, GHz

1.2 1.4 1.6

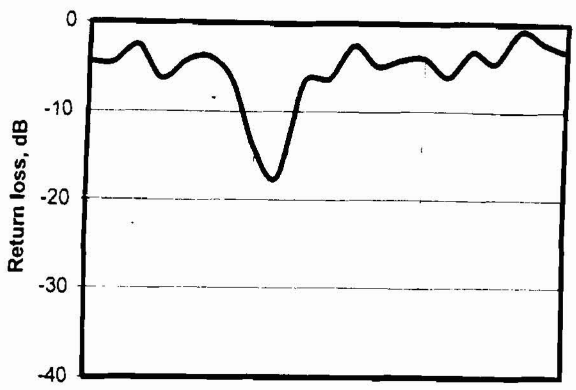

Figure 9. Measured return loss of the RPI antenna with an inset depth of r_w = 24 mm and r_h = 9 mm.

V. CONCLUSION AND FUTURE WORK

The basic rectangular microstrip patch antenna has been successfully optimised using the Micropatch 2.0 simulation software. The size of the structure agrees well with that obtained using mathematical formulations. The tested RPC antenna is well matched at its corresponding 1.58 GHz frequency of operation which indicate very low return losses.

The inset fed RPI antenna was experimentally found to exhibit an almost perfectly impedance matched structure with an inset depth of 22 mm by 9 mm on both sides of the 50 ohm microstrip feeding line. The antenna resonates at a 15 % lower frequency of operation, indicating a reduction size factor of 1.5 compared to the corresponding basic rectangular structure. In addition to having a reduction in size, the inset fed antenna is perfectly matched without any impedance matching circuitry.

Further investigation is currently under way for an identical antenna with the inset feed structure placed at the radiating edge. Initial simulation results using another simulation software showed that the antenna exhibits dual resonance behaviour.

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APPENDICES

Appendix 1

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Patch parameters: cf1.6
[UNIT: mm]

[SUBSTRATE:
 dielectric constant(r)      : 2.95
 loss tangent                : 0.0028
 height of substrate         : 1.57
 thickness of conductor      : 0.035
 sigma of conductor          : 5.882e+007
 surface roughness(r.m.s)    : 0.0024
]
[FREQUENCY(GHz):
 1.6
]
[PATCH: RECTANGLE
 length  : 53.5817
 width   : 66.7095
 ports   : 1
]
[PORT 1:
 x :     17.0404
 y :     0
 type :  0
 Zo(Ohms): 50
 diameter:  1
]
[STATUS: Optimized]
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