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Design and Realization of Corner Reflector Antenna for RF Energy Harvester at 600 MHz Frequency

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Abstract

Microstrip antennas can be applied in many systems, one of which is the harvesting of radio frequency (RF) energy. However, the low gain characteristics of microstrip antennas cannot be avoided. For that reason, reflector is used to increase the gain. This paper presents a design of microstrip antenna with reflector to harvest RF energy from UHF TV. Defected Ground Structure is adopted in the microstrip antenna, to obtain a suitable bandwidth. While a corner reflector is used to achieve a relatively high gain and unidirectional radiation pattern. The results show that the proposed antenna is able to cover all of allocated frequencies for UHF TV in Bandung, Indonesia. The gain is relatively high, up to 7.94 dB at 600 MHz, with low return loss, down to -20.982 dB. The antenna has been tested with rectifier circuit and it is able to produce voltage slightly below 1 Volt.

Index Terms; *Microstrip Antenna; RF Energy Harvester; Corner Reflector*

I. INTRODUCTION

Energy on earth is decreasing due to human usage.For this reason, renewable energy is needed to resolve energy problem. One solution is harvesting RF energy, where an antenna is one of the vital component in the harvester system. Some sources in radio frequency which might be harvested including signal for communication, GPS, and television broadcast signals.

Some antennas for UHF TV frequencies have been reported [1], [2]. These antennas are microstrip based, which has the characteristic of low gain.Therefore, it is needed a method to resolve this issue. Several methods for improving microstrip antennas gain have been reported, including the use of parasitic element and multilayer method [3], [4]. In this paper, the method that has been used to increase the gain of the microstrip antenna on the UHF TV frequency is by using corner reflector.

Corner reflector is one method that was first introduced by John D. Kraus [5] and used to increase the gain of an antenna, in addition to direct the radiation pattern of an antenna toward a particular direction [5]. Usually an antenna with a corner reflector have gain up to 12 dBi [5] and usually the feeder is a dipole antenna. Several studies of angle reflector usage on an antenna have been reported [6], [7], [8], [9]. This paper will explain the effect of a corner reflector on a microstrip antenna in energy harvesting application.This paper will focus on energy harvesting from UHF TV at frequencies (479.25 MHz - 799.25 MHz).

II. ANTENNA GEOMETRY

A. Microstrip Antenna

In this paper, the microstrip antenna design is adopted from [10], and then the antenna is modified to work at lower frequencies.The dimension of the proposed antenna can be seen in Figure 1 and 2. This microstip antenna uses FR-4 as its substrate

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with relative permittivity (εr) 4.3.Substrate height (h)is 1.6 mm.Conductor thickness is 0.035 mm, and the impedance at the feeding point is 50 Ω.

The antenna is basically a microstrip with rectangular patch.The patch is then defected, by removing ¼ circle on the edges of the patch, as can be seen in Figure 1. Figure 2 shows the antenna groundplane that usesa V-Shaped defects. These two defections are meant to achieve wide operating bandwidth. In determining the antenna dimensions, the wavelength comparison method is used. The reference antenna geometry is calculated in terms of wavelength. Then geometry of the proposed which has a different wavelength, is calculated following the reference antenna geometry. Furthermore, the antenna dimensions are optimized using a single patch rectangular antenna calculation approach. The obtained optimal dimension of this microtrip antenna is listed in Table 1.

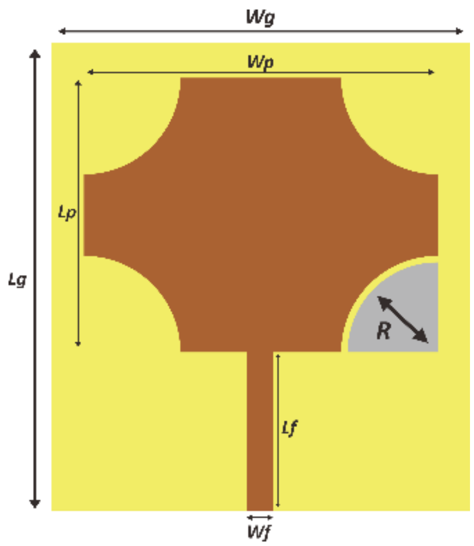

Figure 1 Dimension of Antenna Microstrip (front side)

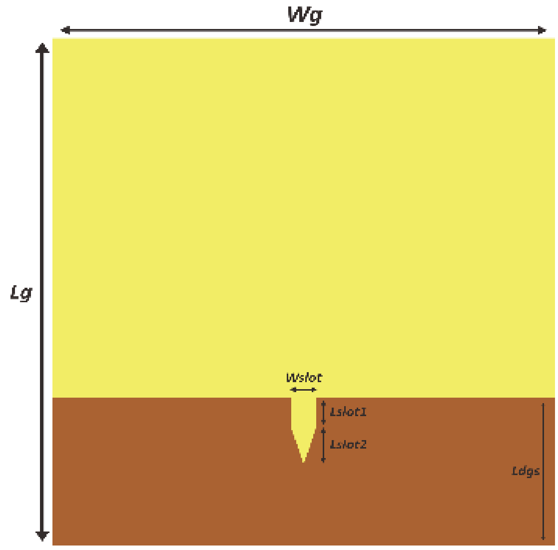

Figure 2 Dimension of Antenna Microstrip (back side)

Table 1

Dimension of the microstrip antenna

Variable	Value (mm)
Wp	144
Lp	139.85
Wg	163.6
Lg	216.106
Wf	3.3
Lf	72.5
R	40.332
Ldgs	69.395
Wslot	1.748
Lslot1	6.062
Lslot2	8.916

B. Corner Reflector

Figure 3 depicts geometry of the proposed microstrip antenna with a corner reflector.To determine the dimension of the corner reflector, calculations available in [11] are utilized. The material used for the corner reflector is aluminum

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with a thickness of 1 mm. Equationsto determine the dimension of the corner reflector is listed in Table 2, while Table 3 list the optimized value from each variable.

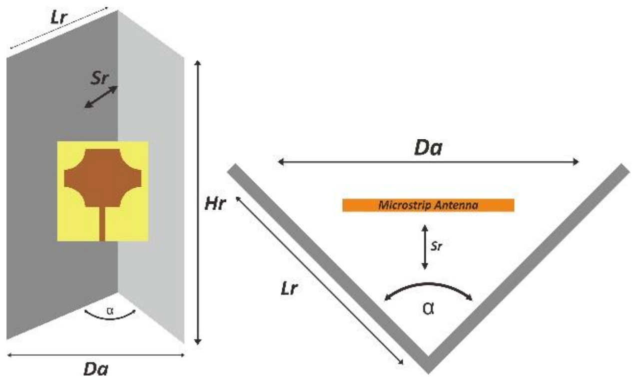

Figure 3 Dimension of Corner Reflector

Table 2

Formula of Corner Reflector

Variables	Equation	Explanation
Da	$\lambda \simeq 2\lambda$	Aperture of corner reflector
Sr	$\frac{\lambda}{3} \simeq \frac{2\lambda}{3}$	Gap between antenna with reflector
Lr	1.2*Lr ≃ 1.5*Lr	The width of the corner reflector
Hr	2*Sr	The length of the corner reflector

Table 3

Dimension of the corner reflector

Variable	Value (mm)
Width of reflector aperture (Da)	500 (1.2λ)
Length of reflector aperture (Hr)	751
Gap between microstrip antenna and reflector (Sr)	166.67
Length of each reflector arm (Lr)	326.33

III. RESULTS AND DISCUSSIONS

CST Microwave Studio 2016 is employed to simulate the antenna design and conduct optimization process. After the optimized design is obtained, the proposed antenna is fabricated and then gone through a series of characteristic measurement

In the optimization of microstrip antennas, some parts of the antenna dimensions affect the return loss parameters and the bandwidth on the antenna which can be seen in Figure 4 until Figure 7. These optimization processes were conducted with 600 MHz as the operating frequency, which is the center of UHF TV band. Figure 4 shows that value of Lslot1 obtained from wavelength comparison process providing the lowest return loss, while further modification was not providing any significant improvement.

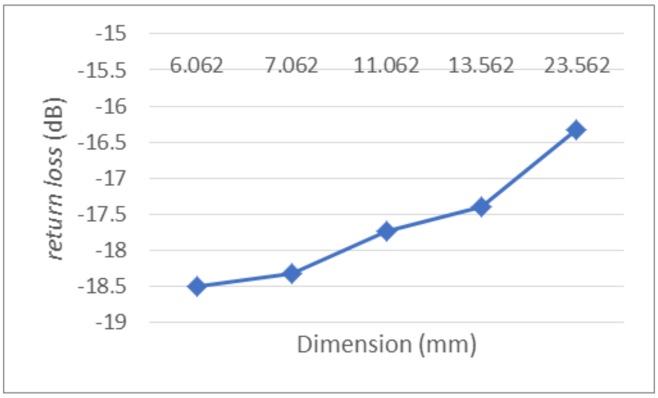

Figure 4 Optimization on dimension Lslot1

Dimension Lslot2 was also varied. However, there was no significant differences in terms of return loss, as depicted in Figure 5. Figure 6 shows the effect of edges cropped radius to the antenna bandwidth. Cropping of 47.832 mm provides the

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widest bandwidth. However, return loss at 600 MHz is better when the radius of cropped area is 40.332, as has been chosen into the final dimension. Height of the groundplane (Ldgs) is also affecting the return loss, where 69.395 mm give the lowest return loss, as shown in Figure 7.

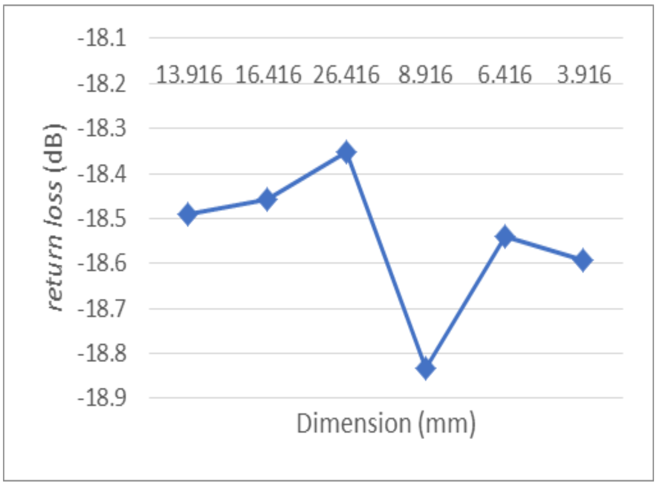

Figure 5 Optimization on dimension Lslot2

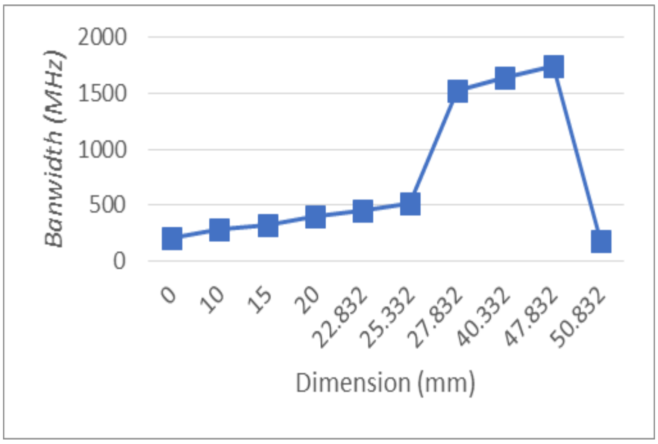

Figure6 Optimization on dimension Radius

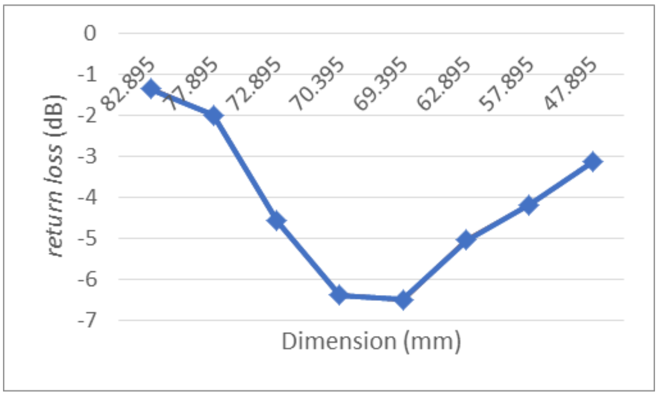

Figure 7 Optimization on dimension Ldgs

The final design has been fabricated and measured. Comparison of the simulated and measured VSWR of the proposed microstrip antenna can be seen in Figure 8. Operating frequency of 462 - 2010 MHz is obtained from simulation, while from measurement, frequency coverage of the fabricated antenna is 447 - 2022 MHz.

At 600 MHz, the simulated VSWR is 1.338, while measurement result is of about 1.049. This difference might occur due to the location of measurement, which was not inside an anechoic chamber, and hence, interferences may introduce some effect to the measurement result. Table 4 list the comparison of simulation and measurement result of the microstrip antenna in terms of VSWR, Return Loss, Bandwidth, Radiation Pattern and gain, where most of the data were measured at 600 MHz.

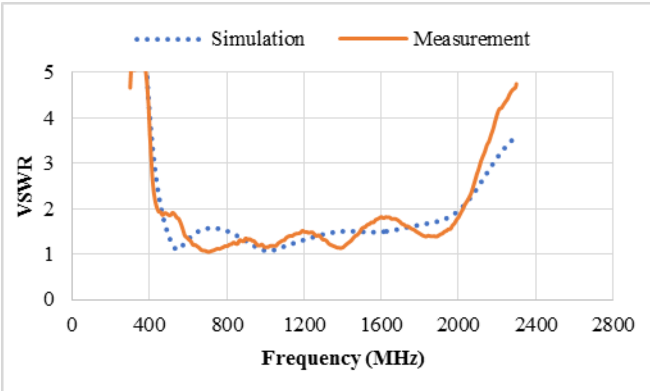

Figure 8 VSWR of Antena Microstrip

Table 4

Antenna microstrip result

Parameters	Simulation	Measurement
VSWR	1.338	1.049
Return Loss	-16.793 dB	-33.91 dB
Bandwidth	1548 MHz	1575 MHz
Radiation Pattern	Omnidirectional	Omnidirectional
Gain	2.271 dB	3.48 dB

After the microstrip antenna has been optimized, a corner reflector is added to obtain higher gain. Geometry of the proposed corner reflector has been explained in Section II. Table 5lists the simulation and measurement results of the microstrip antenna which has been added with the corner reflector. The VSWR and returns loss are increases, which is a normal effect when an antenna is placed near another object. In this case, the reflector is the “another object” that caused this VSWR increment. However, the gain is successfully increased, which is the main objective of the corner reflector usage. Figure 9 shows the comparison of simulated and measured VSWR of the proposed microstrip antenna with the corner reflector. Microstripantenna characteristic without and with corner reflector are compared in Table 6.

Table 5

Corner reflector antenna result

Parameters	Simulation	Measurement
VSWR	1.863	1.203
Return Loss	-10.411 dB	-20.982 dB
Bandwidth	MHz	MHz
Radiation Pattern	Directional	Directional
Gain	10.13 dB	7.94 dB

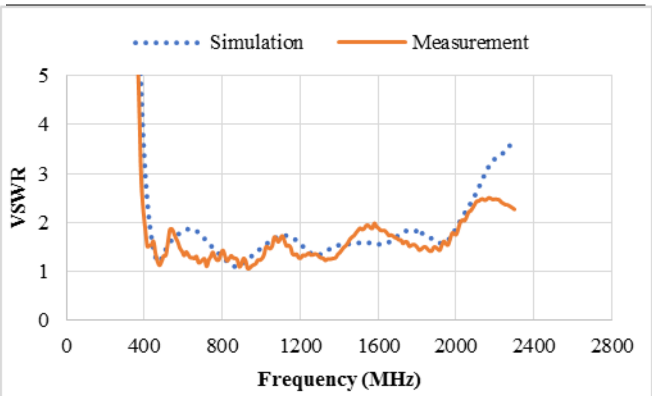

Figure 9 VSWR of Corner Reflector Antena

Table 6

Corner Reflector Measurement Antenna result

Parameters	Without Corner Reflector	Using Corner Reflector
VSWR	1.049	1.203
Return Loss	-12.627 dB	-20.982 dB
Bandwidth	1635 MHz	1569 MHz
Radiation Pattern	Omnidirectional	Directional
Gain	3.48 dB	7.94 dB

The reflector antenna has beenused as a sub-system to harvesting energy from UHF TV band. The measurement uses rectifier which converts RF waves into DC voltages. The rectifiers were obtained from previous research [12], where the circuit areconsists of 3 stages and 7 stages. In the harvesting energy measurement, the antenna is directed to Bandung repeater station. Since the antenna inherits very wide bandwidth, the antenna was also tested by directing itinto one of the closest cellular towers to harvest energy from the GSM 1800 MHz and 900 MHz signals. Figure 10 shows the position of Bandung Television Transmitter Stations relative to the harvester system.

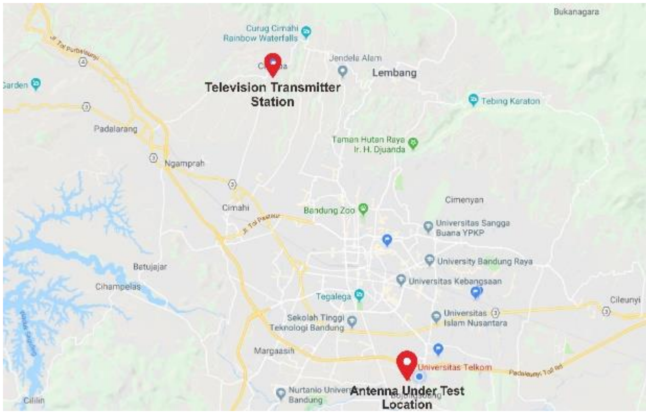

Figure 10 Location of television transmitter station Bandung.

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Figure 11 and 12 shows the charts of measured voltage from the proposed microstrip antenna, without and with corner reflector respectively. It can be seen that there is condition where output without reflector is higher than with reflector. This shortcoming is due to the bandwidth of the proposed microstrip antenna. Without the reflector, the antenna has wide coverage (large beamsize). Added with the fact that the antenna inherits wide bandwidth, signals from other sources from wider angles can be detected and harvested by the system. Whereas with reflector, the proposed antenna is focused only to obtain signals from TV stations.

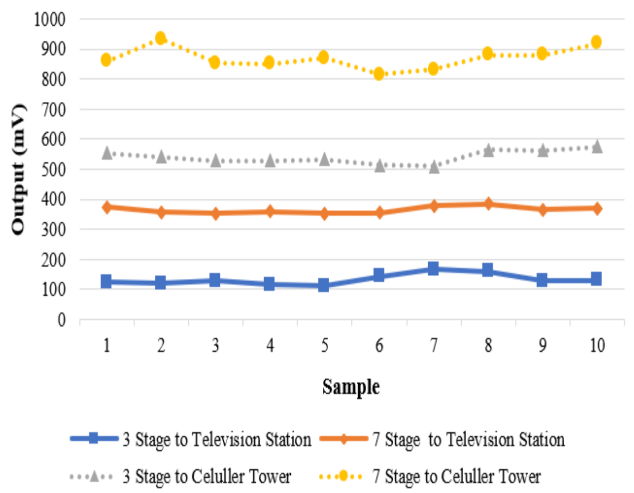

Figure 11 Graph of measured voltage without corner reflector

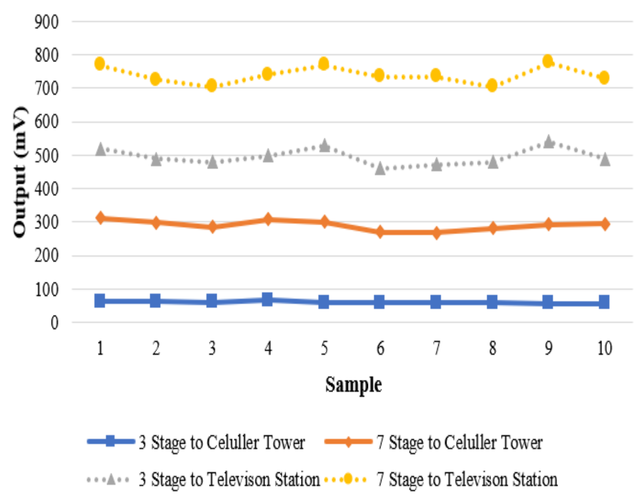

Figure 12 Graph of measured voltage using corner reflector

IV. CONCLUSION

This paper presents a design of microstrip antenna with corner reflector meant for harvesting RF energy from TV station signals. The corner reflector has been proven to increase the gain of the microstrip antenna. Since it has wide bandwidth, signals from other sources are also can be detected and harvested. Hence, it is suitable to be used as a front-end sub-system for energy harvester.

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