Monopole-Like Meander Microstrip Antenna Onboard Microsatellite for Telecommand Applications

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Abstract—**Indonesia requires microsatellites for surveillance & remote sensing applications including disaster management such as forest fire, volcanic activity, flood, or even for communication purpose. The first generation Indonesia microsatellite, called LAPAN-A1 (LAPAN-TUBSAT), has been launched on 10th January 2007 as the starting point to further develop microsatellite technology in Indonesia. The satellite is operated in 400 MHz UHF band. Due to its lightweight and small size requirement, a microsatellite requires an antenna for communication systems (e.g. payload data and data telemetry & telecommand) that suits to the satellite size. In LAPAN-A1, its telecommand system uses a wire antenna that works at the center frequency 437,325 MHz, hence, it requires a relatively large space when its launching process. In order to have more compact UHF antenna for next generation of microsatellite, in this paper we propose a novel small antenna design for telemetry and telecommand applications onboard microsatellite in the UHF band 430–450. The proposed antenna is monopole-like meander-type microstrip antenna, which operates in linear polarization and omnidirectional pattern. We conduct numerical simulation on single antenna design, which able to resonate at 461–481 MHz. The gain of 2.6 dBi is obtained for a single construction. Further, two similar antennas are placed independently onboard on satellite body on –X directed panel (first antenna) and +Y directed panel (second antenna). The simulated results show both antennas are able to work in 428– 468 MHz, with the gain of 2.9 dBi & 2.43 dBi for the first and the second antenna, respectively.**

Keywords— meander-type, microstrip antenna, monopole-like, microsatellite, telecommand, UHF band

I. INTRODUCTION

Indonesia is the largest archipelago country in the world, located between the continents of Asia and Australia and the Indian Ocean and the Pacific Ocean. This position is very strategic, making Indonesia as the world's traffic intersections. Satellite technology is considered as a suitable solution for surveillance and remote sensing purposes. Satellite leads to make a reliable technology to overcome geographical structure of Indonesia. Satellite technology has been developing along with the development of hardware and software technology [1]. Microsatellites (satellites with 10–100 kgs) and nano satellites (satellites with 1–10 kgs) are selected as a start point in the development of satellite technology in Indonesia. This class of satellite is chosen because it has simple subsystem, relatively quick process in research & development and does not require huge costs [2]. Indonesian Space Agency (LAPAN) has began developing microsatellites with the launch of the first generation of microsatellites, called LAPAN-A1 (often known as LAPAN-TUBSAT) on 10th January 2007 and LAPAN-A2 on 27th September 2015. LAPAN also plan to launch the next microsatellites i.e. LAPAN-A3 in 2nd quarter of 2016, respectively.

Antenna is one of the main components in satellite communications system that allows to make link connection between the earth station and satellite subsystems. This communication can be either commanding (up-link) or receiving telemetry data (down-link) and receiving data payload (payload). Hence, satellite requires an antenna with specifications that are adjusted to the intended use.

Selection of the antenna type depends on the availability of electrical power and the spatial size of the satellite body [3]. Wire antennas, horn antennas, reflector antennas, helix antennas and microstrip antennas are commonly used for satellite purpose. Reference [4] reports four monopole antennas are used, which operate in VHF and UHF bands for LEO satellites. Horn antenna is used to obtain wide bandwidth to increase the service capacity of the transponder, is reported in [5]. Reflector antennas are widely used for satellite applications that require high gain and directivity [6] either using active phased array or parabolic reflectors, which operates at K-band frequency and has a scanning capability with a very narrow beam and high gain. In [7], a quadrifilar helix antenna operating in L- and S-band is selected due to its wide bandwidth range and good circular polarization. In addition, microstrip antennas are widely used because of its relatively small dimension allowing to more flexibility in installment on the satellite body. Integration of microstrip antenna with low noise ampifier (LNA) is possible conducted for compactness on the satellite Heinrich-Hertz (H2SAT), which operates at 26 GHz with geostationary orbit [8]. Moreover, microstrip antenna is also used for pico satellite [9] in the S-band with relatively wide bandwidth from 2.05 to 5.7 GHz. To overcome the dimension limitation, miniaturized microstrip antenna is expected. By using meander-line design, antenna can be operated in low frequency such as at 315 MHz [10]. Antenna size becomes very small by 15×5×2 mm. Also, meander type monopole-like microstrip antenna can be used for passive RFID applications in 902–928 MHz [11] and for wireless handheld device in 850–1030 MHz and 1.71–7.8 GHz [12]. From this fact, meander type antenna has some

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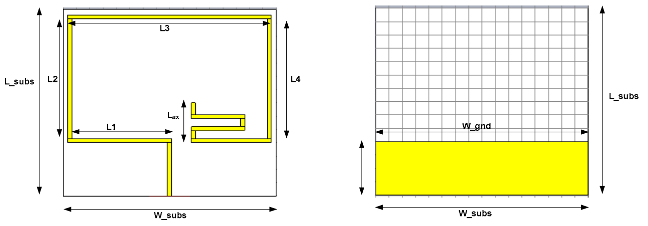
advantages such as compact size/small, easily integrated into wireless devices, and low cost implementation [13].

Therefore, in this paper, we propose a microstrip antenna design by using a meander line to miniaturize the construction in order for the antenna suits the dimension of availaible space in satellite body. The antenna must be operated in amateur radio frequencies (430–450 MHz) with nearly omnidirectional pattern and the minimum gain by 2 dBi with linear polarization for microsatellite telecommand applications. The following section will discuss the antenna design consideration and some simulated results e.g. reflection coefficient, bandwidth, pattern and gain.

II. ANTENNA DESIGN AND SIMULATED RESULTS

Microsatellite has limited power, because the solar panels installed on the sides of the satellite and it does not have a deployable solar panels. This condition limits the satellite attitude control, leading to the satellite stays in thumbling condition in the most of the operation time. Stabilization by using 3-axis only conducted when the satellite is performing its mission, namely when the observation of the earth's surface (video surveillance) is conducted. The satellite requires a lot of interaction between the operator at the earth station by sending a command (telecommand) and receiving telemetry data with half-duplex communications, through a UHF frequency. Therefore, a UHF antenna with omnidirectional radiation pattern is indispensable required. This paper considers about such condition on designing the antenna. The specifications of the antenna is listed in TABLE I.

The geometry of the proposed antenna design is illustrated in Fig. 1. The antenna is numerically designed on an FR-4 epoxy dielectric substrate with the length of 160 mm and the width of 140 mm. The substrate has the thickness, h, of 1.6 mm dielectric constant of 4.3 and its tangent loss of 0.02. This antenna design is limited to the Engineering Model (EM) level, so do not do vibration test and thermal test. Details of the structure parameters are summarized in TABLE II.



(a) (b)

Fig. 1. Geometry of the proposed antenna (a) front view, (b) back view

The proposed antenna is numerically simulated by using finite differential time domain (FDTD) based commercial software (CST Microwave Studio). The simulation results such as the magnitude of reflection coefficient ($|S_{11}|$), impedance bandwidth, gain and radiation pattern are discussed in this section. There are two configuration that have been simulated, i.e. configuration of a single element in free space environment and configuration with two elements onboard on the satellite body model.

TABLE I. DESIGN SPECIFICATION

Parameter	Requirement Description
Resonant Frequency	440 MHz (on satellite body)
$\|S_{11}\|$	≤ -10 dB
Bandwidth	≥ 20 MHz
Gain	≥ 2 dBi
Radiation Pattern	Near omnidirectional

TABLE II. CONSTRUCTION PARAMETERS OF PROPOSED ANTENNA

Parameter	Dimension (mm)	Description
X_feed	3	Width of the feeding
Y_feed	40	Length of the feeding
$L1$	78	Length of patch-1
$L2$	90	Length of patch-2
$L3$	153	Length of patch-3
$L4$	90	Length of patch-4
L_{ax}	39	Length of the meander line
a	3	Width of the line
b	48	Width of the meander-line
w	15	Length of the turn in meander line

A. Single Antenna Alone

Fig. 2 shows the magnitude of reflection coefficient ($|S_{11}|$) of a single element in free space condition. The $|S_{11}|$ at the center frequency 472 MHz is about -13.07 dB with the impedance bandwidth approximately by 20 MHz.

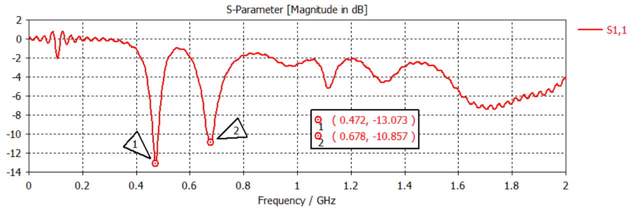
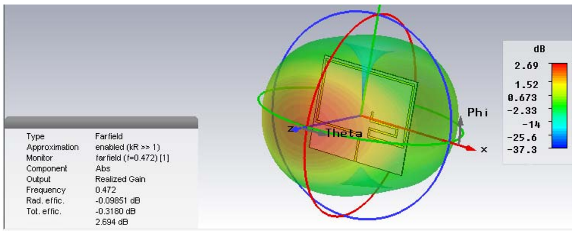


Fig. 2. The magnitude of reflection coefficient (S_{11}) of a single element in free space.

Fig. 3 shows the radiation pattern of the proposed antenna at 472 MHz in three-dimensional view. It can be seen that the wave is radiated in the desired direction (broadside) with peak gain about 2.6 dBi. It is then confirmed with the two-dimensional pattern as shown in Fig. 4. The pattern is almost circular shape (omnidirectional) on the azimuth plane (xz-plane, φ=0) as depicted in Fig. 4(a). This pattern indicates that the radiating energy is almost the same in all directions in the azimuth plane. In contrary, on yz-plane (φ=90°)is eight-shape pattern leads to confirm that the antenna is monopole-like antenna.



Type Farfield
Approximation enabled (kR >> 1)
Monitor farfield (f=0.472) [1]
Component Abs
Output Realized Gain
Frequency 0.472
Rad. effic. -0.09851 dB
Tot. effic. -0.3180 dB
2.694 dB

Fig. 3. Radiation pattern of single element configuration.

B. Antenna on Satellite Body

The second configuration is two of single antenna are placed on the body of the satellite, by putting the first antenna on the -X directed panel while the second antenna on the -Y directed panel. Both antennas have the same orientation, facing on the +Z directed panel, on which a camera for earth surveillance is set. This construction is set to maximize the radiated wave from both antennas into panel b, where this panel is faced to the surface of the earth or earth station during the satellite try to take an image.

Fig. 5 shows the magnitude of reflection coefficient (|S_{11}|) of two antennas. Each antenna is able to operate at the center frequency 440 MHz by -13.13 dB of |S_{11}| with the impedance bandwidth about 40 MHz (428 – 468 MHz).

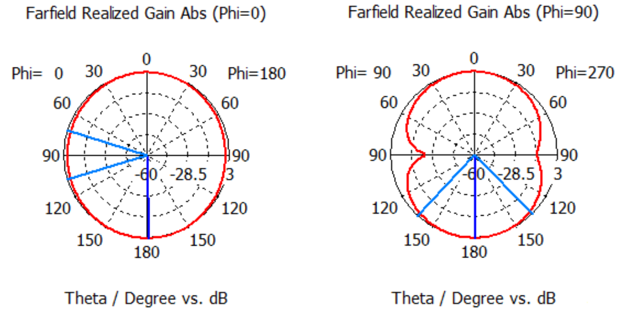


Fig. 4. Radiation pattern in two-dimensional view on (a) *xz*-plane (b) *yz*-plane

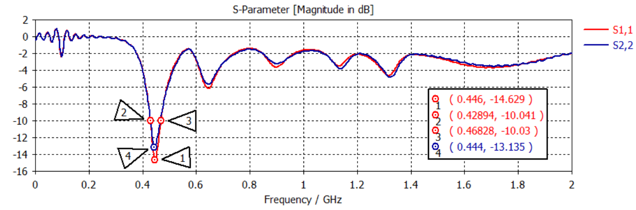
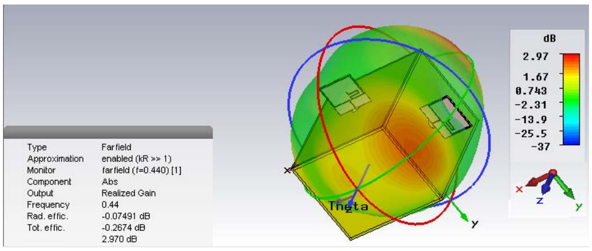


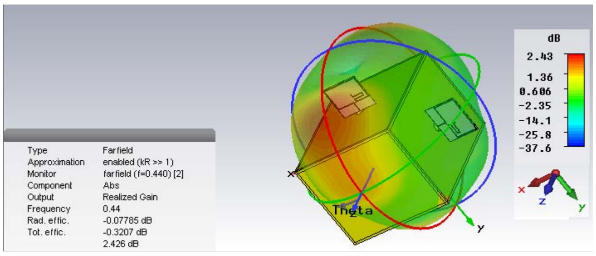
Fig. 5. The magnitude of reflection coefficient (S_{11}) of two antennas that put on the satellite body.

Figs. 6 and 7 show the radiation pattern at 440 MHz for the first and the second antenna, respectively. It can be seen that the wave is radiated in the desired direction (facing to the earth) with peak gain about 2.97 dBi and 2.43 for the first and the second antenna, respectively.



Type Farfield
Approximation enabled (kR >> 1)
Monitor farfield (f=0.440) [1]
Component Abs
Output Realized Gain
Frequency 0.44
Rad. effic. -0.07491 dB
Tot. effic. -0.2674 dB
2.970 dB

Fig. 6. Radiation pattern of the first antenna (right side element).



Type Farfield
Approximation enabled (kR >> 1)
Monitor farfield (f=0.440) [2]
Component Abs
Output Realized Gain
Frequency 0.44
Rad. effic. -0.07785 dB
Tot. effic. -0.3207 dB
2.426 dB

Fig. 7. Radiation pattern of the second antenna (left side element).

When the pattern is confirmed on two-dimensional view (Figs. 8 and 9), both antennas has almost omnidirectional radiation pattern, those are on *yz*-plane (φ=90°) for the first antenna and on *xz*-plane (φ=0) for the second antenna as shown in Fig. 8(b) and Fig. 9(a), respectively. This results show that the maximum beam is directed to the + Z or in the direction onto the earth surface. Finally, the performance of the proposed antenna is summarized in TABLE III.

TABLE III. SUMMARIZED SIMULATED RESULTS

Parameter	**Single antenna**	**Antenna on Satellite Body**	
		The first antenna	**The second antenna**
Resonant Frequency	472 MHz	446 MHz	440 MHz
|S_{11}|	-13.073 dB	-14.62 dB	-13.135 dB
Bandwidth	20 MHz	40 MHz	40 MHz
Gain	2.69 dB	2.97 dB	2.43dB
Radiation Pattern	Omnidirectional	Omnidirectional	Omnidirectional

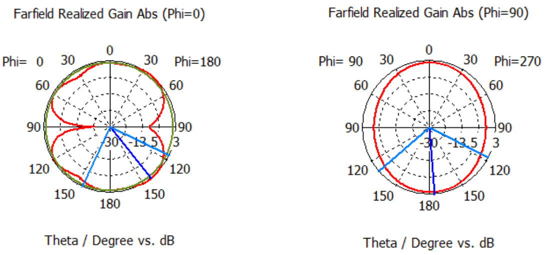


Fig. 8. Radiation pattern of the first antenna in two-dimensional view on (a) *xz*-plane, (b) *yz*-plane

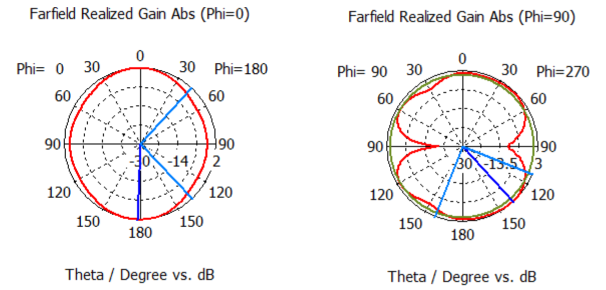


Fig. 9. Radiation pattern of the second antenna in two-dimensional view on (a) *xz*-plane, (b) *yz*-plane

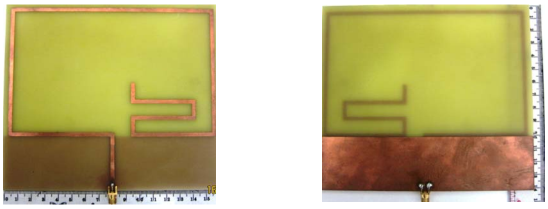

(a) (b)

Fig. 10. Fabricated antenna (a) front view , (b) back view

III. Experimental Results

The antenna is fabricated for operation in the LAPAN satellite working band (430–450 MHz) with the center frequency at 440 MHz, for telecommand purposes as shown in Fig. 10.

The measurement is conducted by measuring the coefficient reflection using PNA Network Analyzer N5221A. Fig. 11 shows the measured reflection coefficient in terms of S_{11} paramater of the single antenna. It seems that good measured input impedance matching characteristic is obtained. The results show that the impedance bandwidth is approximately by 35 MHz (457–492 MHz), that is 75% larger than simulated result. The comparison results are summarized in TABLE IV.

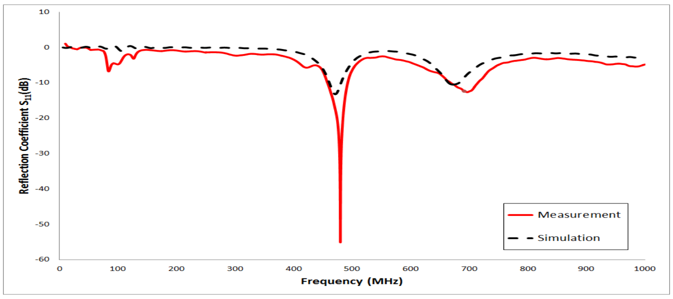


Fig. 11. Simulated and measured reflection coefficient (S_{11}) of the single antenna.

TABLE IV. Comparasion of Single antenna Performance

Result	Bandwidth	Resonant Frequency; $\|S_{11}\|$
Simulation	461 – 481 MHz (20 MHz)	471 MHz ; -13,2 dB
Measurement	457 – 492 MHz (35 MHz)	469 MHz ; -55,2 dB

The single antenna is then mounted on a satellite body (shown in Fig. 12) such that by this construction set up, the reflection coefficient is measured. The measured performance is depicted in Fig. 13 with details of comparison results are summarized in TABLE V.

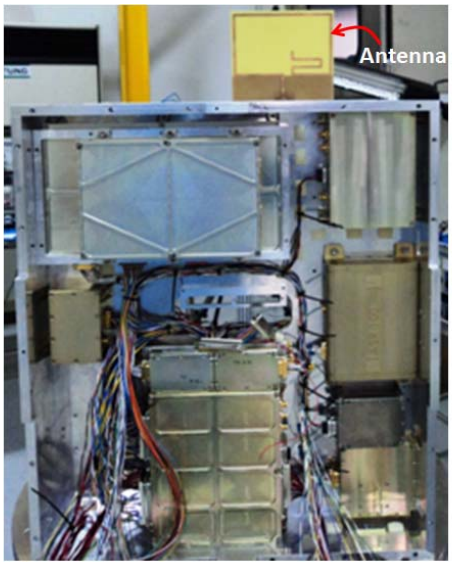


Fig. 12. Single antenna is mounted on a satellite body

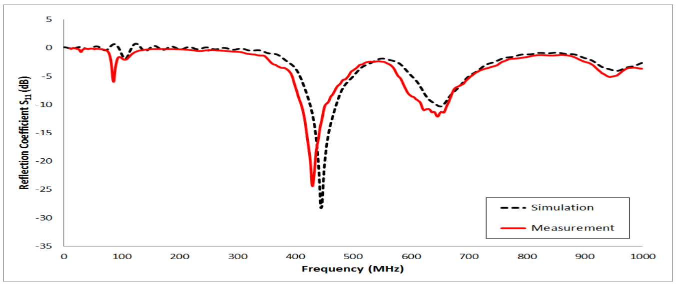


Fig. 13. Simulated and measured reflection coefficient (S_{11}) of antenna on a satellite body set up.

TABLE V. Comparasion of antenna On Satellite Body Performance

Result	Bandwidth	Resonant Frequency; $\|S_{11}\|$
Simulation	425 – 470 MHz (45 MHz)	446 MHz ; -27,9 dB
Measurement	403 – 450 MHz (47 MHz)	428 MHz ; -18,4 dB

From the obtained results, the measured impedance bandwidth agrees with the simulated one even though it is slightly different frequency range. The measured results are in good agreement with the simulated ones. Discrepancies between the measured and simulated result is likely due to imperfection of the simulated material of the satellite body.

IV. Conclusion

This paper has proposed a monopole-like meander type microstrip antenna onboard microsatellite body for UHF telecommand applications. The simulated results show that the proposed antenna is able to operate in desired frequency either in single antenna without satellite body or even when two antennas are placed on the satellite body model. The antenna covers the frequencies from 428 to 468 MHz. The antenna has been fabricated to validate the antenna performances especially in terms of S_{11} parameter by conducting the measurement. The measured result agreed with the simulated one and the operating frequency was suitable in desired operating range. Since the design of the current antenna is stil in engineering model, in the next step, the design will be conducted on a specific substrate by which the antenna is able to be operated at varying temperatures because the antenna will be installed in space environment. In addition, smaller antenna size design is also our near future work.

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