Curved Rectangular Patch Array Antenna Using Flexible Copper Sheet for Small Missile Application

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Abstract—This paper presents the development and design of the curved rectangular patch array antenna for small missile application. This design uses a 0.1mm flexible copper sheet on the front layer and back layer, and a 1.8mm PVC substrate on a middle layer. The study used a small missile model with 122mm diameter size with speed 1.1 Mach and frequency range on ISM 2.4 GHz. The design of curved antenna can be installation on a cylindrical object like a missile. So, our proposed antenna design will have a small size, lightweight, low cost and simple structure. The antenna was design and analysis by a simulation result from CST microwave studio and confirmed with a measurement result from a prototype antenna. The proposed antenna has a bandwidth covering the frequency range 2.35-2.48 GHz, the return loss below -10 dB and antenna gain 6.5 dB. The proposed antenna can be applied with a small guided missile effectively.

Keywords—Rectangular path arrays, small missile antenna.

I. INTRODUCTION

The demands of wireless communication systems are rapidly growing. Future wireless systems will provide various services such as broadband multimedia and high speed access. Especially, the application of military radio technology has become an important topic for microwave communication. In recent years, the increasing interest in antennas and propagations research is an application in military communication devices [1]. The communication link for a missile and military weapons communication devices used to be a wireless network system. Military wireless network system was used for monitoring and tracking of rocket or missile. The communication on missile or rocket was differs from the convectional radiofrequency and wireless communication technologies. The antenna designed for missile needs a bandwidth covered both receive and transmit signals of the missile including some bandwidth because of effect of missile’s speed from Doppler Effect. The speed of small missile was about Mach 2 [2]. So, the antenna resonance frequency will be changed when it’s used on the missile or military weapons. The essential equipment for their wireless communication systems is the antenna which is used for transmitting and receiving a signal. There are many types of antenna applied for the appropriate function and system. But one of the major requirements of a missile and weapons tracking application is a compact and extremely wideband antenna covering the spectrum frequency.

The microstrip patch antenna is better option for military weapons tracking application. Due to their exhibit small size, light weight, low manufacturing cost and easy fabrication. However, frequency shifts when there moving very high speed [3]-[5] because the center frequency will be changed when it’s moved with very high speed around 2 Mach. Recent antenna for missile application development tends to focus on small planar antennas such as bow-tie, elliptical, slot and array antennas [6], [7].

This paper presents a design and analysis of curved rectangular patch array antenna for small missile application. A thin and flexible copper sheet antenna was attached a part of cylindrical PVC substrate. This antenna was designed on small missile model by cylindrical metal object and antenna analysis was conducted by using the CST microwave studio program [8]. The frequency of a designed antenna was used in ISM frequency band at 2.4 GHz. The proposed antenna is realized and experimentally examined, since it has small size, light weight, easy fabrication and low manufacturing cost. In this paper, the antenna will have return loss lower than -10 dB which covered frequency standard of 2.4GHz ISM Band. The average gain achieved in the antenna is more than 6.5 dB over the operating frequency. The advantage of the proposed antenna is that it can be used to small missile for military application.

II. ANTENNA DESIGN AND SIMULATION RESULT

The advantages of the microstrip antennas are small size, lightweight, conformable to planar and non planar surfaces. They are simple and cheap to manufacture using technology. Ideal for installation on guided missile designed to be small.

However, substrate is also important; we have to consider the temperature and other environmental ranges of operation. Thickness of the substrate has a large effect on the resonant frequency and bandwidth of the antenna. Bandwidth of microstrip antenna will increase with increasing of substrate thickness but with limits, otherwise the antenna will stop resonating.

The proposed antenna is designed from calculations and consists of two parts: the patch microstrip antenna and the matching microstrip line at center frequency 2.4 GHz.

Consider, Fig. 1 shows a rectangular microstrip patch antenna of length $L$, width $W$ resting on a substrate of height $h$. the length of the patch must be slightly less than $\frac{\lambda}{2}$ where $\lambda$ is the wavelength in the dielectric medium and equal to $\frac{c}{f_0 \sqrt{\varepsilon_{\text{reff}}}}$ where $\varepsilon_{\text{reff}}$ is the free space wavelength.

From Fig. 1, patch antenna can be design with a given resonance frequency $f_0$, the effective length is given by [9] as:

$$L_{\text{eff}} = \frac{c}{2 f_0 \sqrt{\varepsilon_{\text{reff}}}}$$

(1)

where the expression for $\varepsilon_{\text{reff}}$ is given by Balanis [10] as:
\[ e_{\text{eff}} = \frac{e_r + 1}{2} + \frac{1}{2} \left[ 1 + \frac{d}{h} \right] \frac{l^2}{W} \]

For efficient radiation, the width \( W \) is given by \( B^*l \) and \( B^* \) a [11] as:

\[ W = \frac{c}{2 \sqrt{e_r + 1}} \]

Next, we introduce a simultaneous and multiple commonly used feed techniques on which is the microstrip transmission line. The microstrip transmission line is directly directed to induce excitation. The main advantage is that the feed line and the patch can be printed on the same substrate layer.

**Designing a small missile, bandwidth of the receiving and transmitting signals including bandwidth Doppler Effect. The speed of small missile is around 2 Ma and the result from Doppler Effect is \( \pm 11.07\text{GHz} \) which can be calculated by (4).

\[ f_d = \frac{\gamma v f_0}{c} \]

where:
- \( f_0 \) is the transmit frequency (Hz)
- \( v \) is the speed of missile \( \left( \frac{m}{s} \right) \)
- \( c \) is the speed of light \( \left( \frac{m}{s} \right) \)
- \( f_d \) is the signal frequency Doppler Effect (Hz)

Fig. 2 Schematic of the purpose antenna (Straight)

Three types of feed network: tapered li-es, combina tion of \( l^*\Omega, 50 \Omega \) a-d \( 70 \Omega \) lines, and a corporate-feed network

![Image](image_url)
frequency 2.4 GHz. So, we has a modification of the parameters of the antenna to adjust the frequency resonance to 2.4 GHz as shown in Fig. 4. The result of simulation shows that we can adjust L1 equal to 52mm to make a resonant frequency 2.4 GHz.

![Image](image-url)

Fig. 4 Reflective coefficient (S11) of patch array antenna curved on PVC tube with difference 4°.

Fig. 5 Simulation result of E-filed radiation pattern.

Fig. 6 Simulation result of H-filed radiation pattern.

III. MEASURE RESULT

The prototype antennas were fabricated from flexible COP sheet with the same dimensions and electrical properties as simulated model shown in Table I except L4 as was explained in the previous section. The prototype antenna made from flexible 'oppe' sheet and curved on PVC tube as shown in Fig. 7. The prototype antennas were characterized in terms of return loss and radiation pattern using an Agilent HP8722D vector Network Analyzer, as plotted in the anechoic chamber. The result of simulation compared with a measurement of prototype ith resonant frequency at 2.4 GHz as shown in Fig. 8.

![Image](image-url)

Fig. 7 Prototype patch antenna arrays curve on PVC Tube.

Fig. 8 Reflective coefficient (S11) of prototype antenna comparing simulation and measurement result.

The prototype antenna is laid on XY plane and curved in XZ plane. The E-fields and H-fields radiation patterns of curved patch array antenna were measured as shown in Figs. 9 and 10, respectively. The E-plane of the E-field radiation pattern shown in Fig. 9 has a 6.5° bandwidth. This measurement result agrees with simulation result that the curved patch array antenna has a radiation pattern as 0°-ni-directional, a frequency width is 2.35-2.48 GHz and average gain in all directions is 6.5 dB. This was enough to serve as a wideband missile application.

Fig. 11 shows a range of bandwidth from 2.35 GHz at -20 dB. This bandwidth covers the range of the missile which has Mach of movement of 2-3 and calculated from the equation of the Doppler Effect.
The advantage of the proposed antenna was designed with a cylinder PVC tube and cylindrical surface when it is installed on a small missile. The missile application, which can be curved or bent along the cylindrical surface, is shown in Fig. 11 Reflective coefficient (S11) than -20 dB of purposed antenna compare between simulation and measurement result.
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