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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 arrays 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 where 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, and 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 purposed 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 $\lambda / 2$ where λ is the wavelength in the dielectric medium and equal to $\lambda_0 / \sqrt{\varepsilon_{reff}}$ where λ_0 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:

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \quad (1)$$

where the expression for ε_{reff} is given by Balanis [10] as:

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$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

For efficien radiation, th width W is given by Ba l and B artia [11] as

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (3)$$

Next, we in roduce a si plest and m st commonly used f ed techniqu which is t e microstrip transmission line. icrostrip tra smission line is connect d directly t the tch to induc excitation. he main ad antage is th t the f ed line and t e patch can e printed on the same substrate l yer.

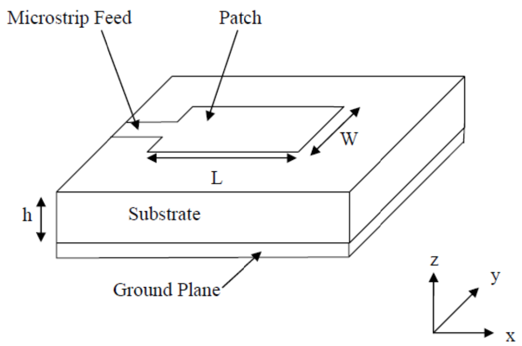
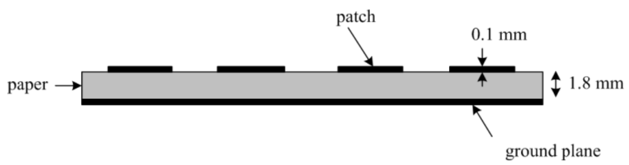
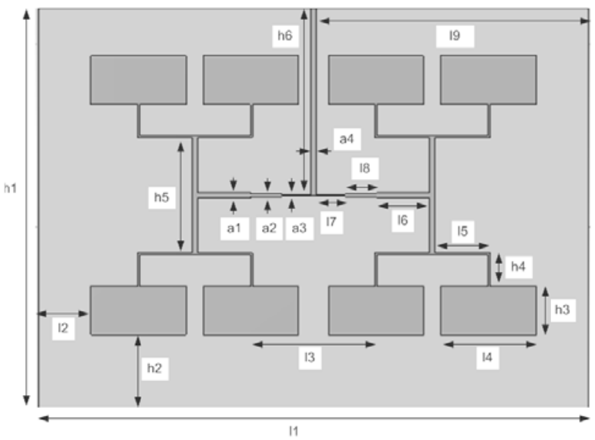


Fig. 1 Micros rip Patch Ante na



(a) op view



(b) F ont view

Fig. 2 Schematic of urpose antenn (Straight)

Three types of feed net ork we e us d: tapered li es to atch 100Ω p tch elements to a 50Ω inpu : combination of 100Ω, 50Ω a d 70Ω lines; and a corp rate-feed ne wor odeled wi h multipl -section uarte -wavel ngth imp dance transf rmers. The t chnique wa chosen for t is desi n because t presented better simul tion results in imp dance matc ing and ante na response. The input port of ntenna was fed into the center of s rip line of he ante na. The siz of the micr strip line w s calculated on the enter freque cy at 2.4 GHz with 50Ω 70Ω and 100Ω imp dances as sh wn in Fig. 2.

T e patch arra antenna w s designed a propriately for an pplication o small cylin er missile. ente -to-ce ter spacing between the patches i more than 0.5λ in order to obta n a proper b lance betwe n antenna g in and radiat on mai lobe shape. The purpose antenna mo el used the t in cop er 0.1 mm. or the patch array [7] on front layer nd gro nd layer at the back of the PVC s bstrates wit a thic ness of 1.8 m. Fig. 2, wi h the param ters in Table .

TAB E I
DIMENSI NS PARAMETER OF PURPOSED A TENNA

Parameter	Size(mm)	Parameter	Size (mm)
l1	300	h1	220
l2	28.5	h2	41
l3	68	h3	27
l4	52	h4	18
l5	29.75	h5	63
l6	29	h6	102
l7	15.75	a1	3
l8	17	a2	2
l9	148.5	a3	1
a4	3	a4	3

Designing a antenna f small missile, bandwi th nee s to cover both receivi g and tran mi ting signals incl ding bandw dth fro D ppler Effect. The speed of sma l missile is a ound 2 Mac at the frequ ncy of 2.4 GHz and result from Doppler Effe is ±11.07 GHz which an be c lculated by ( ).

$$f_d = \frac{2vf_0}{c} \quad (4)$$

whe e

f_0 is the tr nsmit freque cy (Hz)

v is the s eed of missil (m/s)

c is the s eed of light (m/s)

f_d is the si nal frequen y Doppler Ef ect (Hz)

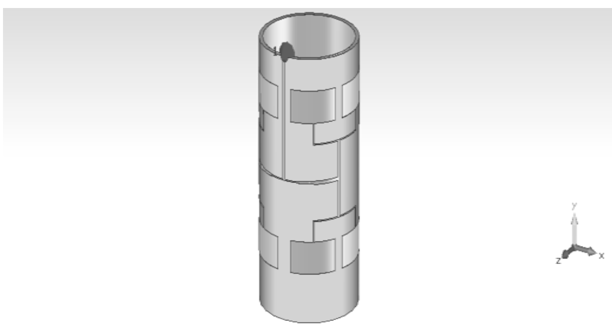
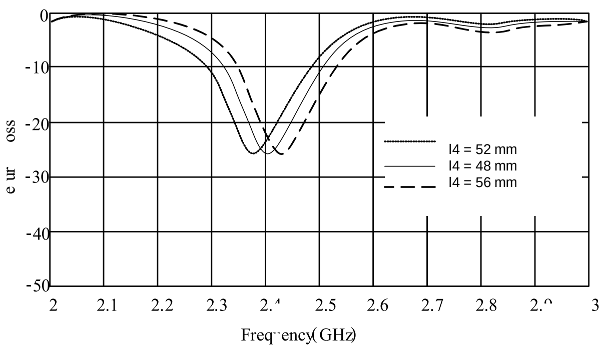


Fig. 3 Model of pu posed antenna curved on cyli drical PVC tu e

However, whe we curved patch array on PVC tub at 130 mm. diamete as shown i Fig. 3, the imulation re ult sho s that the a tenna is not working at he same ce ter frequency 2.4 GHz. So, e has a m dification of the rameters of he antenna t adjust the fr quency reso ance ck to 2.4 G z as shown i Fig. 4, The esult of simu ation s ows that w can adjust l4 equal to 52mm to m ke a r sonant frequ ncy 2.4 GH .



F g. 4 Reflective coefficient (S 1) of patch arr y antenna cur ed on PVC tube ith ifference *4*

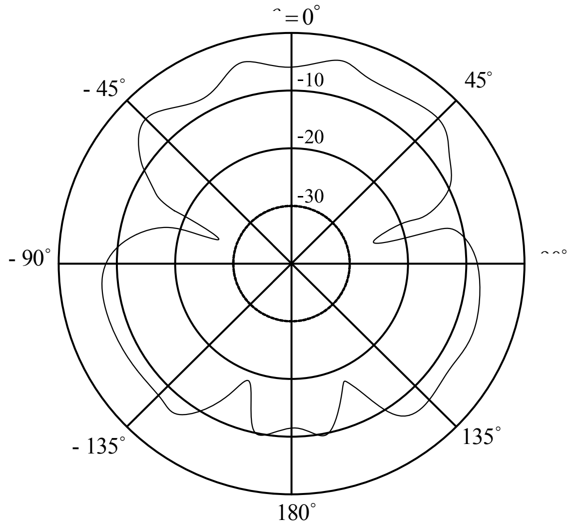


Fig. 5 Simulation resul of E-filed radiation pattern

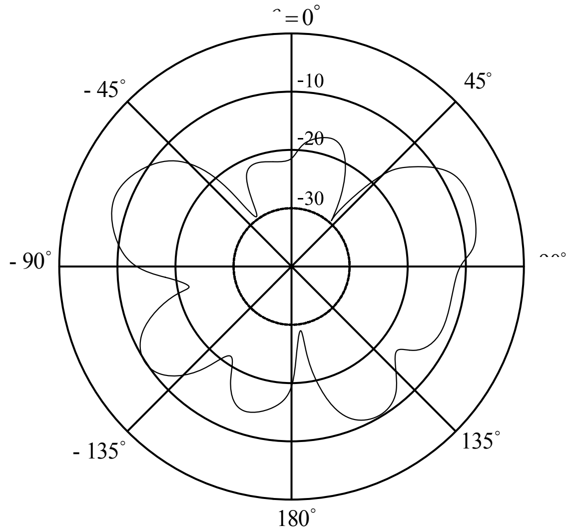
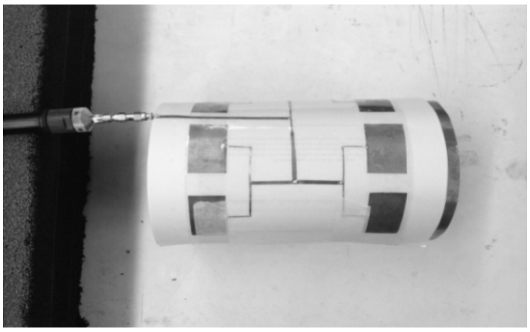


Fig. 6 Si ulation resul of H-filed rad ation pattern

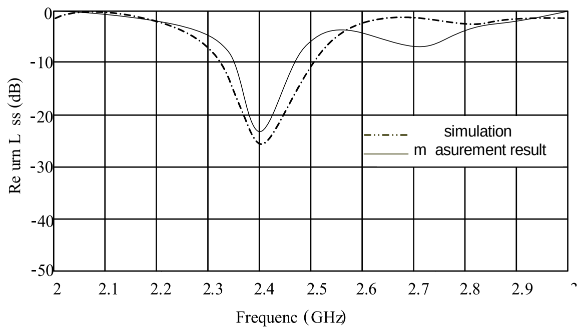
T e E-field an H-field radi tion patterns of curved pa ch arra antenna were shown on F gs. 5 and 6, r spectively. he lan of the elect ic field direc ion shown in Fig. 5 has ab ut 7 d directional ain.

III. MEASURE ENT RESULT

T e prototype antennas w re fabricate from flexi le cop e sheet wi h the same dimension arameters nd elec rical properti s as simulati n model an shown in Ta le I ex ept *l4* as w had explain d reviousl . The protot pe ante na made fr m flexible oppe sheet and curved on PC tube as sho n in Fig. 7 The prototy e antennas re char cterized in erms of retu n loss and adia ion patt rn usin an Agilen HP8722D icrowave ector Netw rk Ana yzer, is perf rm in the an choic chamb r. The result of sim lation comp re with a m asurement o prototype ith reso ant frequency at 2.4 GHz as shown in ig. 8.



F g. 7 Prototype f patch anten a arrays curve on PVC Tub



Fi . 8 Reflective oefficient (S11) of purposed ntenna compa e etwee simulation an measurement result

T e antenna is laid on XY– lane and cur ed in XZ- la e. The E-fields and -fields radi tion patterns of curved pa ch arra antenna wa measured a d shown on Figs. 9 and 0, resp ctively.

T e plane of t e E-field rad ation pattern shown in Fi . 9 has round 6.5 d directional ain. This me surement re ult agre s with simul tion result t at curved pat h array ante na has a radiation attern as O ni-direction l, a freque cy an width is 2. 5-2.48 GH and avera e gain in all dire tion is 6.5 B. This wa enough to se for a s all mis ile applicatio .

F g. 11 shows a range of b ndwidth fro the 2.38-2. 35 GH at -20 dB. This bandwidth covers t e range of he mis ile which ha 2 Mach of movement s eed, calcula ed fro the equation of the Doppl r Effect.

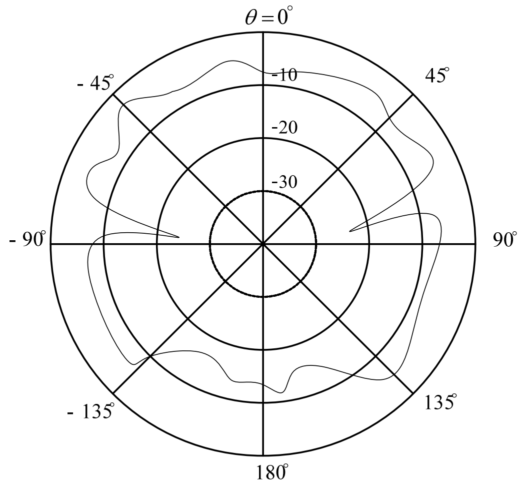


Fig. 9 E-filed radiation pattern from measurement

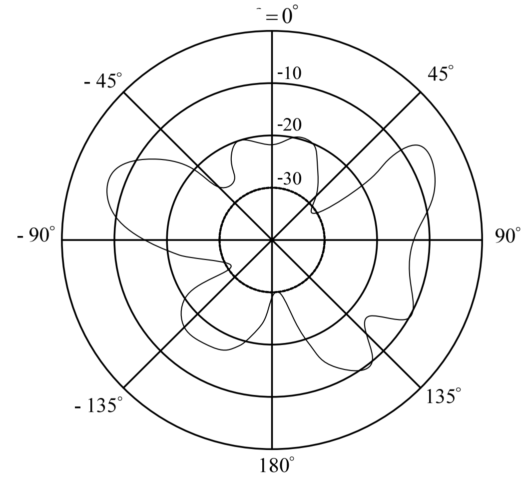


Fig. 10 H-filed radiation pattern from measurement

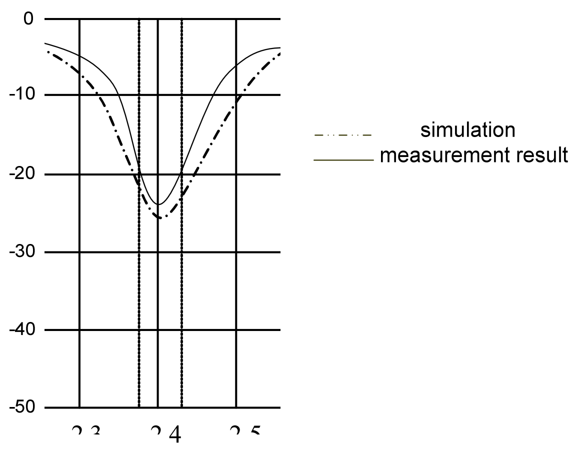


Fig. 11 Reflective coefficient (S11) than -20 dB of purposed antenna compare between simulation and measurement result

IV. Conclusion

This paper presented the patch array antenna for a small missile application, which can be curved or bent along the cylindrical surface when it is installed on a small missile. The proposed antenna was designed with a cylinder PVC tube and antenna analysis was conducted by using the CST microwave studio program. The ISM frequency of a designed antenna has center frequency at 2.4 GHz. In measurement, it is found that the proposed antenna has about 400 MHz (2:1 VSWR) frequency bandwidth which covered frequency range 2.35 - 2.48 GHz. The average gain achieved in the propose antenna is about 6.5 dB over the operating frequency. This antenna has Omni-directional radiation patterns at the center frequency of 2.4GHz and bandwidth covers all frequency effect on Doppler Effect (' 11.072 kHz). The advantage of the proposed antenna is that it can be used with small missile for military application.

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