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Back Radiation Reduction in Jean's Slot Patch Antenna Using Reflector

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Abstract: In this paper, the minimization of back radiation by means of sophisticated designs using the Jeans slot patch antenna with reflector is discussed. We focus on decreasing the back radiation and increasing the gain and directivity. It is shown that, the reflecting layer with an air gap of 5 mm with first layer maximize the gain. The simulation results show that the antenna parameters are enhanced reaching a gain up to 9.14dBi with directivity 9.21 dB with -30 dB return loss.
Keywords: Jeans substrate, Reflector, Slot Patch Antenna.

1 Introduction

The textile antenna is a special kind of antenna made up of textile materials with rigid materials. Textile antennas are of different kinds, such as electrically conductive fabrics and denoted electro-textiles which are used substrates. In the antenna, the insulating parts are made up of dielectric materials. The main intention of applying antenna in the textile garment is for sensing functions. These are effective in detecting the body temperature, heart rate, position, external temperature, and humidity. Generally, textile antenna has fabric material such as cotton, jean, and felt as substrate materials have low dielectric constant value between 1 to 2.Kavitha&Swaminathan 2018 [1] have proposed monopole textile antenna with a new substrate material like jeans cotton and Teflon for medical applications such as monitoring the patient health. Luigi Vallozzi, Hendrik Rogier and Carla Hertleer have designed a dual polarized patch antenna for ISM band (2.4-2.4835 GHz), as wearable textile systems for rescue workers 2008 and 2009 [2]. The wider application of medical, military and other field encourage the researchers on full filling the need for specialized design in textile-based antennas. Improved design can guarantee the off-body communication of the information sensed by the sensors and transmitted to the base stations. Another main objective of using these embedded textile components is the reused facility alongside the guarantee of washing the suit.

The Federal Communications Commission (FCC) in 2002 [3-9] supports commercial use of UWB bands from 3.1 to 10.6 GHz. On the UWB transmission antennas there is no need of a larger battery and also no need of transmitting a large-power signal to the recipient. Implementing the UWB antenna, with textile material succeeds and improve its parameters by means of flannel as substrate [10-18]. There are several enhancements are raised in recent years, especially in the wearable electronic devices. The main motto of this works is to fulfill the real-time requirements like minimum power consumptions, robust and comfortable for wearable applications [19,20, 21]. Broadly speaking, for communication purposes, these wearable antennae are utilized as mobile computing, wireless communication, public safety, tracking, and piloting. Some of the significant properties include gain, reflection coefficient (S11) and radiation pattern, etc. These properties are analyze and calculation was discussed detailed in [13-15]. The impact factors like easy installation, lightweight, low cost, low intensity, low profile, and planar configuration make the involvement of textile-based antennas on the high priority. For textile based antennas, planar microstrip patch antennas (MSP) are perfectly suited [3-8], but MSP results in a low gain, which causes this system unpopular [6-8]. Normally, the textile material has less dielectric constant in nature which minimizes the rear lobe. This architecture maximizes the antenna's gain [17]. Additionally, the gain is further improved by means of utilizing flexible dielectric materials [18] like denim, cotton, leather and felt as a substrate [20] on MSP.

Reflectors are an effective key for achieving the antenna's

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gain and directivity. A U shaped reflector with a planar antenna is designed for attaining high gain and low profile [20]. In order to improve the gain and bandwidth [21], a slot antenna with more than one reflector is discussed. Another mechanism such as a magneto dielectric dipole antenna with cavity shaped reflector is designed for enabling more gain and large front to back ratio [22]. In certain works, an aperture coupled antenna with reflector is proposed for improving the gain and directivity [23].

In this work, we propose Jean's substrate with reflector for reducing the size and back lobe. This results in enhancement of gain and directivity.

Improved design of textile patch antenna proposedin [24], uses Polyester textile as a substrate to achieve better return loss and gain. Reversed E shaped textile antenna [25] utilize fabric material as substrate, provides 79% efficiency along with impedance bandwidth of 15%.A novel Electro textile patch antenna uses oven electro textile material [26], reduces Specific absorption rate and implement efficient antenna .E-textile Origami Dipole antenna with Graded Embroidery [27], uses graded embroidery substrate, and increases the RF performance of the antenna, such as efficiency of the antenna. Dual band microstrip patch antenna using Felt substrate enhances the performance of the various antenna parameters.

Issues in the conventional Patch antennas such as less gain and directivity are improved by using textile substrate. In the proposed antenna design, jeans substrate with reflector is used to reduce the surface waves hence antenna performance is improved.

This paper is structured as follows; in the section 1 introduction is described. In chapter 2 proposed methodologies is described clearly. Section 3 describes Designing of an antenna.Section4 has the result and discussion, section 5 explains Fabrication of jeans Patch antenna, section6 illustrates measured results, final conclusion of section 6.

2 Experimental Sections

2.1 Implementation of Patch Antennas

The proposed antenna design has two layers, one is radiating patch placed on the jeans substrate, and another one is reflector which is placed at the bottom of the jeans substrate. The patch antenna design is an extraction from conventional square patch antenna with some adjustments like removal of proportioned parts from both the corners. And a square slot is placed at the center of the design. Next to the implementation of the second layer which placed 5mm below the first layer. The second layer has two copper films, on which the upper copper film performs as reflecting plane and bottom copper film as the ground. The Jeans substrate is placed between the copper films of thickness of .07mm. Let's see the proposed design architecture is illustrated in Fig 1 and 2.

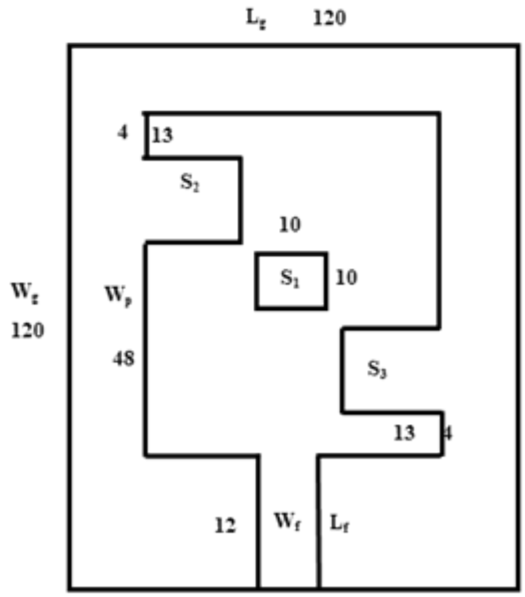

Fig.1: Jeans slot patch antenna geometry (all dimensions are in mm).

Fig1 the proposed design with Jean's slot patch antenna is shown. Where L_g=120mm (ground length); W_g=120mm. (ground width); L_P=56mm. (patch length),W_p=48mm (patch width); W_f=12mm (feed width), L_f=3.5(feed length), S1,S2,S3 are Square slots.

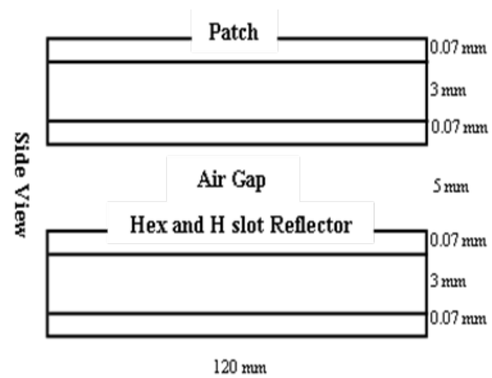

Fig. 2: Side view of jeans slot patch with reflector.

The Side view of jeans slot patch antenna is clearly viewed on fig 2 with the reflector. The proposed patch size is 56×48m.m with an air gap as well as hex and h slot reflector. In this design, the jeans substrate is used with a permittivity of 1.67 and dielectric loss tangent is .0019.

Fig, 3 demonstrates the unit cells of reflector surface which comprises of nine hexagonal- shaped elements with the H slot at its center.

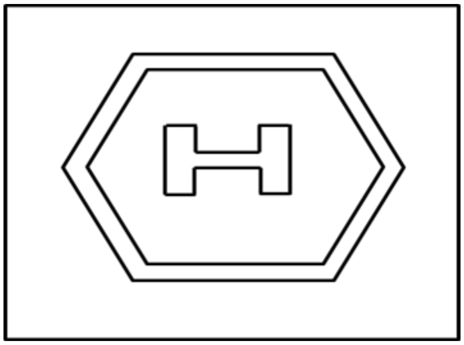

Fig. 3: Unit cell of the reflector surface.

7	8	9
4	5	6
1	2	3

Fig. 4: Segmentation of the reflector.

Fig 4 represents segmentation of the reflector in unit cells. There are nine unit cells and the main reason for implementing reflector in the second layer is redirecting the backside radiation to the main lobe direction. By means of this proposed implementation directivity and gain are improved effectively.

The relationship between gain and directivity is expressed below;

G = ηD

Where

η = Radiation efficiency of an antenna

G = Antenna Gain

D = Antenna Directivity

SMA connector is used to connect the 20×3.5 mm feed line using insert feed.

3 Designing

The proposed micro strip patch slot antenna with reflector is designed for 2.45 GHz. The parameters which are required for calculations are:

Patch width calculated by using the below equation

$$W = \frac{C_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where,

W = Width of the Patch

C_o = Light speed.

ε_r= dielectric constant

Effective refractive index:

Refractive index is nothing but calculating how fast light propagates through the material. Here the refractive index of the patch antenna is important factor affecting the antenna efficiency. The fringing field is the field where electromagnetic field is transformed into the ground through the substrate and air from the antenna. In the inhomogeneous substrate, the value of effective refractive index (ε_{reff}) is represented as per the below equations.

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

At fringing, the antenna's dimension is enlarged by the quantity (ΔL), by which the patch length increases (ΔL), which is demonstrated by the below equations.

$$\Delta L = .421h\frac{(\varepsilon_{reff} + .3)\left(\frac{w}{h} + .264\right)}{(\varepsilon_{reff} - .258)\left(\frac{w}{h} + .8\right)}$$

Where

'h'= height of the substrate

Patch Length (L) is designed by

$$L = \frac{c_o}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (1)$$

Ground plane length (L_g) and the Width (W_g) are designed by

$$L_g = 6h + L$$
$$W_g = 6h + W$$

The proposed Microstrip patch slot antenna with reflector is designed for 2.45 GHz. The parameters which are required for calculations are:

Width:

Patch width calculated by using the below equation

$$W = \frac{C_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$

Where,

W = Width of the Patch

C_o = Light speed

ε_r= dielectric constant

4 Simulated Results

Return loss and VSWR are straightly related to the patch size. But Gain and Directivity are Inversely Proportional to the patch size.

If the patch size is varied from its original value then VSWR and Return loss is increased, which indicates that feed line and antenna are not perfectly matched. Hence antenna performance of the antenna is degraded i.e.Gain and directivity decreased. For the original size with reflector case only high Return loss=-30 dB, low VSWR=1.06 which shows perfect matching is achieved for the original size .Hence antenna parameters such as Gain=9.14 dBi and Directivity=9.21dB are also improved for the original size.

Fig 5 shows the Jeans slot antenna's return loss at with and without Reflector. From which the red line indicates the reflection coefficient without reflector and the blue line indicates the reflection coefficient with reflector is -28dB and -30dB respectively.

This variation in results proves the impact of implementing Reflector in the proposed design.

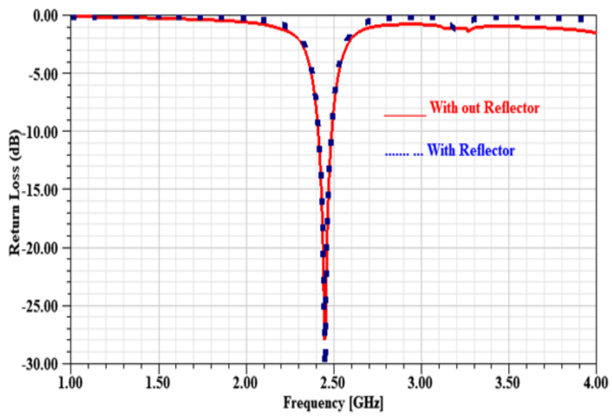

Fig. 5: Return loss of the Jeans slot antenna with and Without reflector.

Air Gap Variation: On varying the Air gap with 3mm &10mm, it results on reflection coefficient and VSWR which are indicated in table 1. Here there is a slight decrease in gain but directivity remains as per the original air gap. A best gain and directivity is obtained on the original air gap. Fig 6 demonstrates Jeans slot antenna's VSWR with and without the reflector. The red and blue line indicates the variation of VSWR with reflector and without a reflector values are 1.09 and 1.06 respectively.

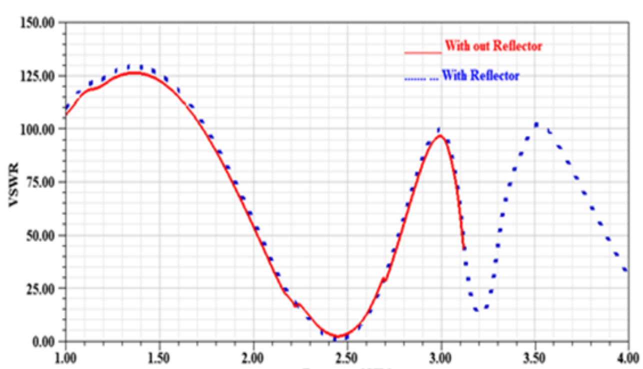

Fig. 6: VSWR of the slot jeans antenna with and without reflector.

Feed length variation: On the variation of feed length, there is an increment on return loss and VSWR. According to the antenna parameters which are not acceptable i.e. it reflects the mismatching of feed line with the patch antenna. There is a slight decrease in gain from its usual value whereas directivity remains unchanged. The fig 7&8 show gain and directivity of the Jeans slot antenna with and without Reflector respectively. The feed length variation between with and without reflector can be determined by the blue and red lines respectively. Perfect match is achieved, when feed line is fixed at the appropriate place of the antenna. For the original size feed length is perfectly fixed with the antenna hence we get increased gain and directivity.

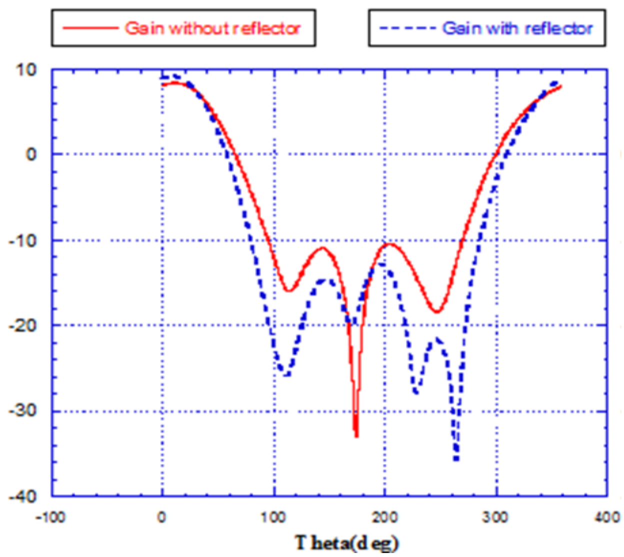

Fig. 7: The gain of the Jeans slot antenna with and without Reflector.

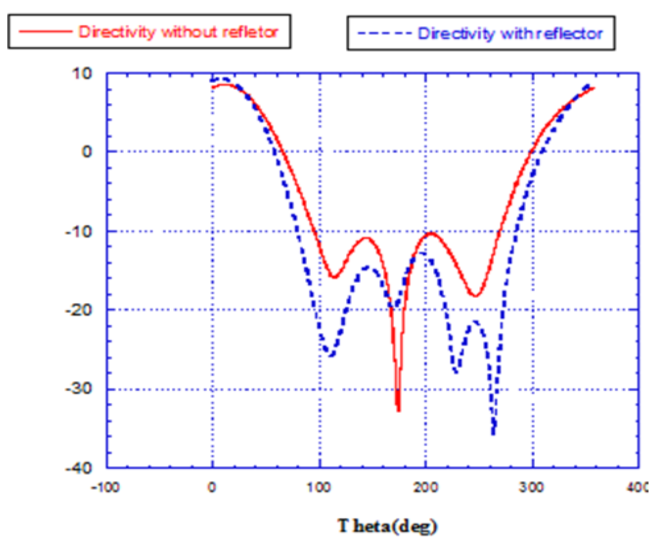

Fig. 8: Directivity of the Jeans slot antenna with and without reflector.

5 Fabrication of Jeans Patch Antenna

For fabricating the prototype Jeans patch antenna, the following steps to be processed.

The jeans thickness is measured by gauge thickness and the single layer thickness is .07 mm.Generally, on the stitch at the ends with the jeans substrate dimension 120m.m×120m.m, a thickness of 3 mm is obtained by the hoard. These residual Jeans are replaced by scissors. The Jeans substrate is placed in between the annealed copper ground plane 120×120 mm, and the patch made up of annealed copper of 56×48mm. Then making slots which are placed at the right and left corners on the patches are with the dimensions 13×4mm. also create square slot at the center with the dimensions 10×10m.m. Front view of the slot patch antenna is shown in Fig 9.

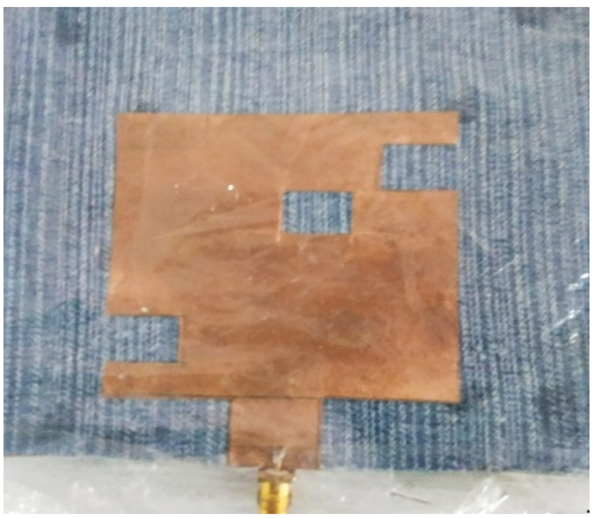

Fig. 9: Front view of the fabricated slot patch antenna.

In a similar manner, hexagonally shaped with H slot reflector layer is designed with the dimensions as per the unit cells of reflector surface(in fig 3) as shown in fig 10

From below the first layer, the second layer is placed at 5 mm air gap with the overall size of the patch is 56x48mm.

Fig. 10: Back view of the slot patch antenna (reflector).

6 Measured Results

The proposed antenna is fabricated by implementing jeans substrate. Fig 11 gives a clear view of our testing setup, by using the testing setup (Network analyzer) Return loss and VSWR are measured and compared with the simulated value. A VNA is a test system that enables the RF performance of radio frequency and microwave devices to be characterized in terms of network scattering parameters, or S parameters. Network analyzers are used mostly at high frequencies can range from 5 Hz to 1.05 THz.

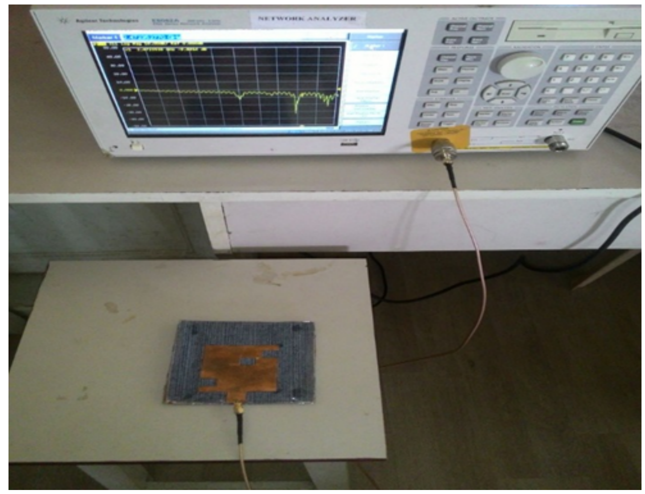

Fig. 11: Measurement Setup for measuring the return loss and VSWR.

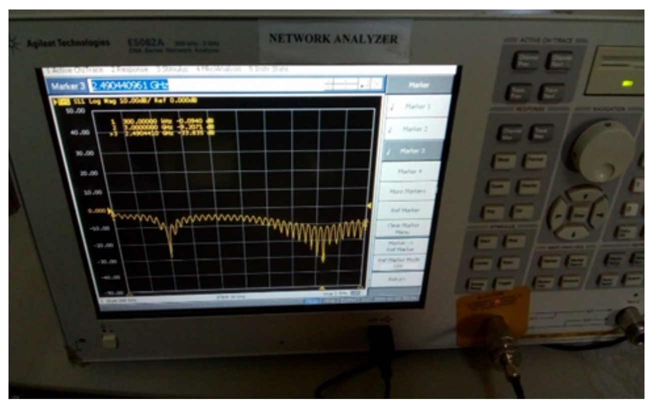

Fig. 12: Measured value of Return loss for the proposed Structure of antenna with reflector.

The Measured Return loss Value is -33 dB and the simulated value is -30 dB. The measured return loss value is shown in fig 12.Normally, the return loss of the antenna should be at least -10 dB. If the return loss value is less than -10 dB indicates reflected waves are high i.e. radiated waves from the antenna is less and efficiency of the antenna is decreased and vice versa. For the proposed design the Return loss is equal to -33 dB which indicates the antenna is completely matched with the feed line and antenna can effectively works.

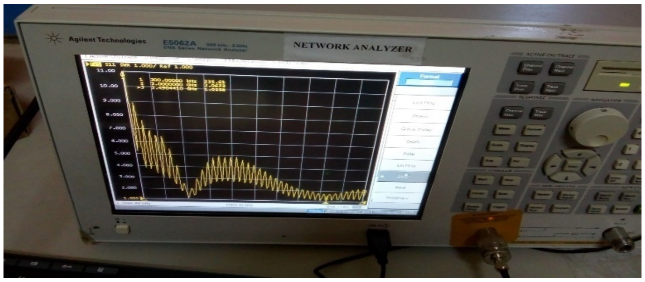

Fig. 13: Measured value of VSWR for the proposed structure of antenna with reflector.

Table1: Changes in antenna parameters by varying antenna design parameters.

Parameter	Change in Parameter	Antenna Parameters					
				VSWR		Gain	Directivity
		Simulated	Measured	Simulated	Measured		
Size	Original size (56*48 as shown in fig 2)	-30	-33	1.06	1.02	9.14	9.21
	Increase in size (70 * 58)	-5.06		3.53		7.3	7.3
	Decrease in size (40 * 43)	-35.64		1.033		7.55	8.54
Air Gap	3mm	-15.51		1.4		9.14	9.21
	10mm	-11.82		1.68		9.14	9.21
Feed Length	Increased	-13.17		1.56		8.88	9.21
	Decreased	-8.7		2.14		8.45	9.21

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The measured VSWR is 1.02 and the simulated one is 1.06 which is shown in fig 13. For the best case the VSWR value is equal to 1.VSWR is a parameter describes how well the antenna is matched with feed line.If VSWR is 1 then it indicates antenna is perfectly matched with the feed line. For the proposed design both the simulated and measured values are almost nearer to one indicates the reflected wave is less i.e. the antenna is perfectly matched. The final obtained results conclude, on the aspect of return loss as well as VSWR both simulated and measured results are almost same.

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