Development of Portable Electromagnetic Radiation Protective E-Textile

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Abstract

This paper describes the way of protecting human tissues from the electromagnetic waves by using portable textile protecting shield on garments. The shield consists of yarn of stainless steel and a dyed yarn of metallic aluminum particle. The Protective shield can be assembled with the garments easily and can be used as a portable shield to use it in different garments. Technical textiles are used instead of conventional textiles material because of its excellent performance. Human Comfort has been kept in mind. The efficiency of the protective Clothing is good and the cost is low for general people, which is less than 2 USD.

Keywords:

Protective, Technical Textile, Radiation, shield

1 Introduction:

The electronics industry has grown rapidly than any other industry in the whole world. We are using the electronic equipment in our daily lives and the electromagnetic interference (EMI) exposes to us as they operate in close proximity as radiation level of different electronic devices is shown below in table 1(Chudasama, 2013)(Brzeziński et al., 2009).

Table 1 : Frequency of Different Electronic Devices

Electronic Devices	Frequency (MHz)
Garage door openers, alarm systems Around	40
Cordless phones	40 to 50
Baby monitors	49
Radio-controlled airplanes Around	72
Radio-controlled cars Around	75
Wildlife tracking collars	215 to 220
MIR space station	145 to 437
Cell phones	824 to 849
Cordless phones Around	900
Air traffic control radar	960 to 1,215
Global Positioning System	1,227 and 1,575
Deep space radio communications	2,290 MHz to 300

The multifunctional flexible fabrics have lightweight and they have the resistance to electromagnetic radiation. They also contain the basic properties and structures of textile material(Amiet, Nahavandi, & Kaynak, 2007). When staple fibers are mounted with stainless steel, they show good resistance towards electromagnetic interference(Nanocomposites, 2012). Now, the electromagnetic inference has become a potential health hazard and by the cumulative exposure, various diseases like increased risk of DNA, RNA deformation and brain tumor can be a threat(Apreutesei et al., 2014; Deprospero & Picard, 1990). There is research going on all over the world of preventing radiation. The radiation cannot be prevented at a time but the level of radiation can be lessened by using a protective shield.

Electromagnetic shielding is done by limiting the flow of electromagnetic fields between the two areas by using a barrier or applying a protection medium. If the barrier has the high conductivity or dielectric constant or high magnetic permeability, then it can obstruct the electromagnetic radiation (Fig-1)(Bonaldi, Siores, & Shah, 2014)(Maity, Singha, Debnath, & Singha, 2013).

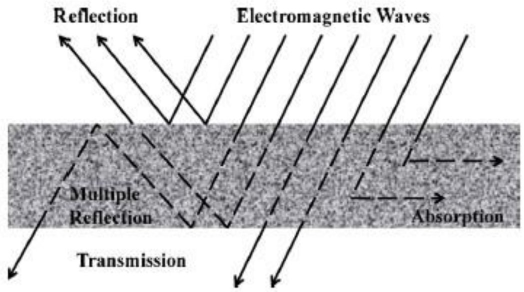

Figure 1: Mechanisms of Electromagnetic shielding

Laminated composites show good conductivity property and thus they can protect well from electromagnetic radiation. The wave transmission matrix can be used to calculate the plane wave shielding properties. Single-layer fabric shows less protection than the multilayer fabric (Chen, Lee, Lin, & Koch, 2007; Geetha et al., 2010).
Structures have an effect on electromagnetic shielding. Different structures show different electromagnetic shielding. Two conductive fabric of the same material can have different potential towards shield having different structures. The fabric which is asymmetrical has better shielding property than the symmetric plain weave (Ouyang, Karayianni, & Chappell, 2005)(Rybicki, Brzeziński, Lao, & Krawczyńska, 2013).
The efficiency of electromagnetic radiation protection depends upon the electromagnetic reflection. But the absorption of electromagnetic radiation is needed for some particular situation. The electromagnetic radiation efficiency can also be controlled by changing the resistance property (Geetha et al., 2010)(Ghosh et al., 2018).
The conductive polymerized coating can give a fabric electromagnetic shielding property and it can be easily compared with the carbon, silver, iron etc. metallic particles(Maity & Chatterjee, 2018). Wearable antennas can be used as a radiation shield. If the two yarn or fiber are kept about 2 mm the plane is designed to be an electromagnetic antenna (Liu, Lu, Qiu, & Li, 2011; Rashid, Tushan, Ahmed, & Tushar, 2019).

2 Designed Architecture:

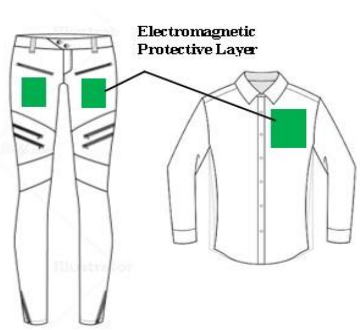

Figure 2: Design Architecture of Electromagnetic shield

The designed architect is developed to understand the most probable location to prevent the human organ from electromagnetic radiation. These three locations are mostly exposed to electromagnetic radiation so they are primarily located and further some more locations can be added. The conductive fabric structure is 2/2 twill rib and it is shown below in the figure-3.

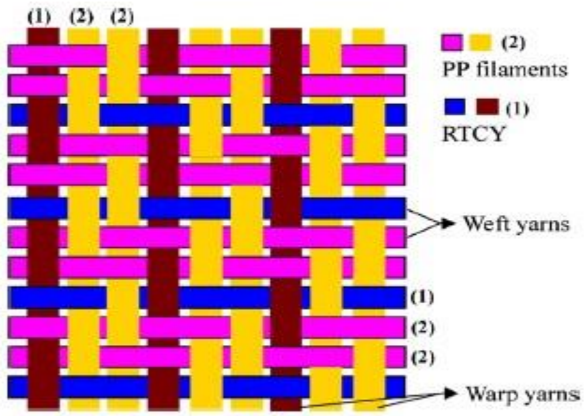

Figure 3: sketch of a 2/2 twill conductive fabric structure

3 Methodology:

3.1 Yarn dyeing with metallic particle:

Initially, yarn was rinsed with distilled water having no heavy metal components. Then after measuring the aluminum sulfate, it was mixed with water in the dye bath then slowly raising the temperature the yarn was then poured into the water bath. The dye bath temperature was then slowly raised to 104^0 F for 45 minutes. Again, coming back to the room temperature, the yarn was then kept for drying.

Recipe:

- 200 grams of fiber
- 40 grams/2 rounded Tablespoon + 2 teaspoons of aluminum sulfate
- A container to dissolve the aluminum sulfate
- A large stainless-steel dye bath
- Heat source (104^0 F)

3.2 Yarn of stainless steel:

Yarn made from stainless steel has good electrical conductivity and has resistance to electromagnetic inference. By cutting the thread from stainless steel the yarn is formed. The specification is shown at the below.

Table 2: Specification of the Stainless Steel

Si Content (%)	.39
C Content (%)	.02
Wire Diameter	.018 mm - .15 mm
Surface	Bright Annealed

3.3 Making Cloth with Meshing both SS and Copper yarns:

The cloth is woven in the loom. The machine in this process used is the CCI machine. Firstly, the yarn-dyed with aluminum particle should be inserted and the yarn of stainless steel is inserted. The tension of both yarns should be equal and must be adjusted. The piece of cloth is two-layer because of the strength it requires (figure 4).

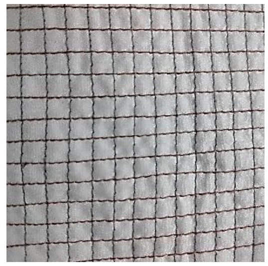

Figure 4: After making the woven fabric in the loom.

The fabric is then embedded with aluminum layer so that it can provide more radioactive protection (fig 5).

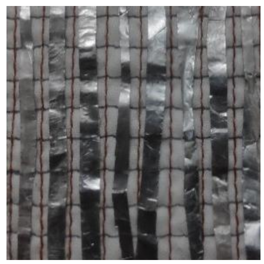

Figure 5: After adding Aluminium finish layer

3.4 Setting the Cloth with Garments as Portable:

Using an external clip, the radioprotective cloth can be adjusted with the garments to the inner side of the pocket and the Chest portion of the shirt. The cloth should be assembled with the garments so that wearer does not feel uncomfortable.

4 Material Selection:

Customer requirement is very essential while planning to design a product. By having the customer requirement, some technical features should be fixed. Some of the customer requirements are protection, comfort, accuracy, lightweight, low cost and some of the technical features are resin coating, structure, metallic yarn, metallic particle, dyes particle. The strong relationship is given 10 points, the medium relationship is given 5 points, and the poor relationship is given 2 points. Weighted total scores and percentage scores are considered for ranking the technical properties.

Table 3: QFD shows the relation between customer requirements and technical features

Strong Relationship ● 10 points
Medium Relationship ○ 5 points
Poor Relationship ▲ 2 points

Customer Requirements	Rating	Technical requirements: Resin Coating	Structure	Metallic Yarn	Metallic Particle	Dyes particle	Our Product
Protection	6	●	●	●			G
Comfort	5	●	○		▲	○	F
Accuracy	4	○	●	○			G
Light weight	3				○		F
Low Cost	2	●		●	○	▲	G
Score		150	125	100	35	35	
Percentage score		34	28	22	8	8	

To find the material that fits best to the product for the better performance we used the digital logic method for determining the relative importance of each technical property and gave them according to weights shown in table 3.

Firstly, with the help of the digital logic method, the relative importance was identified.

Table 4: Determining the relative importance of goals using the digital logic method

Number of positive decisions=n(n-1)/2=10												
Selection criteria	1	2	3	4	5	6	7	8	9	10	Positive Decisions	Relative emphasis co-efficient
Electromagnetic Resistance	1	1	1	1							4	0.4
Conductivity	0				0	0	1				1	0.1
Elasticity		0			1			1	0		2	0.2
Corrosive			0			1		0		1	2	0.2
Efficiency				0			0		1	0	1	0.1
	Total Number of Positive Decisions										10	

The performance index of Stainless Steel and Copper has been calculated and we have seen that the performance index of Stainless Steel is better and so we choose to use Stainless Steel.

Table 5: Calculation of performance index of Stainless Steel and Copper

Selection Criteria	Weighted Factor	Stainless Steel		Copper	
		Scaled Property	Weighted Score	Scaled Property	Weighted Score
Electromagnetic Resistance	0.4	80	32	50	20
Conductivity	0.1	70	7	65	7
Elasticity	0.2	50	10	50	10
Corrosive	0.2	30	6	75	15
Efficiency	0.1	90	9	50	5
Material Performance Index			=64		=57

The performance index of Aluminum and Iron has been calculated and we have seen that the performance index of Aluminum is better and so we choose to use Aluminum.

Table 6: Calculation of performance index of Iron and Aluminum Filter

Selection Criteria	Weighted Factor	Iron		Aluminum	
		Scaled Property	Weighted Score	Scaled Property	Weighted Score
Electromagnetic Resistance	0.4	70	28	70	28
Conductivity	0.1	70	7	65	6.5
Elasticity	0.2	50	10	60	12
Corrosive	.2	60	12	40	8
Efficiency	.1	50	5	80	8
Material Performance Index			=62		=62.5

5 Results:

Electromagnetic radiation tester is used for testing the radiation before applying the radiation protective e-textile and after applying the radiation protective e-textile. We can see that after applying an electromagnetic radiation shield, radiation can be reduced to a great volume.

Table 7: Test Result of electromagnetic radiation before and after applying the shield

	Before Applying Shield		After Applying Shield			
No. of Experiment	E – Field (V/m)	H – Field (μT)	E – Field (V/m)	H – Field (μT)	% Reduction of E- Field	% Reduction in H-Field
1	550	1.8	30	0.02	94.55	98.89
2	600	2.2	20	0.11	96.67	95.00
3	530	2.6	11	0.07	97.92	97.31
4	580	1.95	33	0.03	94.31	98.46
5	520	2.3	17	0.10	96.73	95.65
6	590	2.2	40	0.01	93.22	99.55
7	585	2.3	30	0.12	94.87	94.78
8	565	2.4	20	0.15	96.46	93.75
9	590	2.3	35	0.05	94.07	97.83
10	550	2.5	18	0.01	96.73	99.60
11	530	2.5	47	0.05	91.13	98.00
12	570	2.6	15	0.07	97.37	97.31
13	580	2.5	13	0.13	97.76	94.80
14	540	2.6	10	0.19	98.15	92.69
15	570	2.2	15	0.14	97.37	93.64
Mean					95.82	96.48

6 Cost:

The total cost of developing the radiation protective E-textile is only 1.39 USD but if it is produced in bulk, the total cost will be less than it is now.

Table 8: Cost of materials for development

Material Name	Price (USD)
Stainless Steel Yarn	.24
Conductive Copper Yarn	.35
Conductive Aluminum Yarn	.40
Aluminum Protective layer (Extra)	.10
Others	.3
Total	1.39

7 Conclusion:

The core impact of this research was to develop the portable radiation protective textile cloth. The radiation protective shielding cloth can be used to different garments and also it is reusable. The radiation is reduced in a substantial percentage (reduced 95.82% of E-Field & 96.48% of H-Field). The cost of the product is cheap (less than 2 USD) so that anyone can buy and avail it easily. The shielding cloth is made of mainly stainless steel and cellulosic yarn dyed with aluminum particles. The cloth is user comfortable.

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Biography:

Md Mamunur Rashid is an Assistant Professor in Industrial and Production Engineering at Bangladesh University of Textiles (BUTEX). He received his B.Sc. degree in Industrial and Production Engineering from Bangladesh University of Engineering and Technology (BUET), in 2013. He acted as corporate professional in both Textile and Garments units of DBL Group to apply Industrial Engineering tools and techniques prior to starting his academic career as a Lecturer at BUTEX in 2015. He has been involved in different research projects in the area of multidisciplinary optimization, CAD/CAM, artificial intelligence application, industry 4.0, supply chain management. He is Lean Six Sigma Green Belt certified practitioner of lean manufacturing in the Textile and Garments Industries. Mr. Rashid is a life member of the Bangladesh Society for Total Quality Management (BSTQM).

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