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FURTHER RESEARCH ON THE QUADRANGULAR PRISM OF SELF-INVISIBILITY (I)

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ABSTRACT

A quadrangular prism of self-invisibility has been further researched for its applications to vehicles. Its structure has been calculated and demonstrated strictly and quantitatively, according to the laws of reflection of light and geometric principles. Furthermore, the invisible effect with respect to the position of an observed point was investigated when the observed point shifted from the most-clear position. Finally, a unique extrapolation is given and discussed with the comparison of their invisibility rates. Based on detailed analyses, some significant conclusions for such an application on vehicles have been obtained.

KEYWORDS:

stealth technology, camouflage technology, invisible, vehicle, automobile Industry

1. INTRODUCTION

No one denies the significance of stealth technology for military aviation. Scientists design special structures for the fuselage so that it directs signals away from the radar receiver to an extreme extent. There are two approaches to get such a goal, either making the fuselage with an angular shape of straight faces and sharp angles, or covering the body of the plane surface with some special materials that absorb radio signals radiated from radars [1-4].

Second category of research focus has been on the visible light issue. For common objects, the basic research is on how to bend the light bounced from the objects observed. The basic principle for such invisibility is to use refractive materials, metamaterials or reflective mirrors to guide electromagnetic rays so that the visible light can escape from the eye of observer; in this way, the invisible effect is obtained [5-10].

At present, the application of camouflage technology is confined to military industry and seems far from the daily lives of humans due mainly to the consideration of both confidentiality and security. In reality, if we can camouflage some objects used in daily life, it will provide some benefits. One type of unique design was reported firstly in literature [11], which is the potential to camouflage the pillar that supports the windshield, side windows and the roof in all sorts of vehicles. The invisible support pillars in an auto will provide drivers with a much better field of vision around the vehicle during driving. It is a quadrangular prism of self-invisibility, which can camouflage itself, without depending on any traditional materials, such as fractive crystals, or reflection mirrors. In this paper, the structure of this quadrangular prism has been formulated by geometric principles. Furthermore, the process of deduction to get an essential extrapolation set-up also has been calculated. In order to describe theinvisible objects objectively and quantitatively, a certain new physical quantity should be produced which is used to measure and

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compare with both the quadrangular prism and its extrapolation. Finally, some essential conclusions will be obtained matching both intuition and strictly mathematical derivation.

2. FORMULIZING THE QUADRANGULAR PRISM OF SELF-INVISIBILITY

(a) HOW TO PARAMETERIZE THE STRUCTURE OF THE QUADRANGULAR PRISM

For a concrete application, such as the pillars to frame the windshield and side windows in all sorts of vehicles, the direction and separation between the driver and frame keeps nearly constant with only a small scope of variation. Therefore, flare angle of observer to object seen ϕ can be regarded as a known parameter for some pillar EF with a certain size as shown Figure 1. Accordingly, we select a suitable value of h the height of base triangle of triangular prism. In a word, the structure of this quadrangular prism is determined by following three factors: (1) the height of base angle of triangle h; (2) ϕ determined by the ratio of the size of pillar camouflaged EF to the separation between the pillar to the observed point; and (3) the size of EF. Using geometric principles and the law of reflection, it is not difficult to establish and solve the following equations:

$$\delta + \theta + \alpha = \frac{\pi}{2} \text{ ------------------------------------ } (1)$$

$$\phi + 2\theta + \alpha = \frac{\pi}{2} \text{ ----------------------------------- } (2)$$

$$\delta' + \theta' + \alpha' = \frac{\pi}{2} \text{ ----------------------------------- } (3)$$

$$\phi + 2\theta' + \alpha' = \frac{\pi}{2} \text{ --------------------------------- } (4)$$

$$2h\csc\delta\cos(\delta + \alpha) + h\csc\alpha = EF \text{ ------------- } (5)$$

$$2h\csc\theta'\cos(\theta' + \alpha') + h\csc\alpha' = EF \text{ ---------- } (6)$$

$$S1 = h^2(\cot\theta + \cot\delta + \cot\theta' + \cot\delta') \text{ -----------} (7)$$

$$S2 = h[\cot\theta + \cot\delta + \cot\theta' + \cot\delta']\cos\phi\,[EF + h(\cot\theta + \cot\delta - \cot\theta' - \cot\delta')\sin\phi] \text{---------} (8)$$

Let ϕ = 5 o , h =1 and EF= 4h as the initial conditions, from equation (1), (2) and (5) we get θ = 29.4o , δ = 34.4o . Similarly, from equation (3), (4) and (6) we get θ' = 23.2o , δ' = 28.2o and α' = 38.6o . From (7) and (8), the area of four triangle S1=7.43; and the area of isosceles trapezoid S2 = 28.95, respectively. After careful calculations, all the parameters to determine structure of prism are decided shown in Table 1.

(B) EXTRAPOLATING THE QUADRANGULAR PRISM

From (1)(2),(3)(4) we get, obviously, when the separation between pillar camouflaged to observer goes to infinite, ϕ goes to zero, consequently, $\delta = \theta = \delta' = \theta'$; both equation (5) and (6) change into such an equation: $LD = h(1 + \tan 2\theta\cot\theta)$ which is exactly to be the formula already reported in [11] as shown in Fig. 2.

(C) COMPARING THE INVISIBILITY RATE OF THE QUADRANGULAR AND RECTANGULAR PRISM

For simplicity of calculation and comparison, two ideal abstract models are built as shown in Fig. 3. The parameters are determined properly and listed in Table 2. Next, in order to provide a scientific language to depict all sorts of invisible prisms, one new concept should be produced, so that more efficient and quantitative descriptions can be executed. Here a new concept proposed is invisibility rate that is defined as the ratio of flare angle that light can go through to total flare angle from observer point towards object seen. For instance, in Fig. 3, the angle, light going through without any obstacle, divided by the total angle α is defined as an invisibility rate with respect to flare angle α . The data of several angles showing the invisibility rate for some flare angles are shown in Table 3 which are illustrated in Fig. 4.

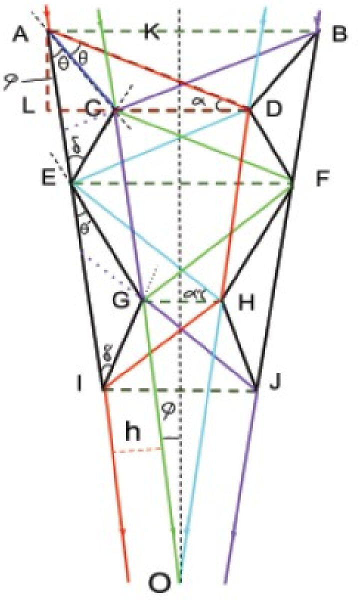
Similar to invisibility rate with respect to flare angle, another physical quantity to depict the properties of some invisible prism is invisibility rate with respect to separation deviation. Table 4 and Fig.5 show the invisibility rate as the function of the observer point shift from the most-clear position. When the observer point shifts from origin (0,0) along oy axis up and down, the invisibility with respect to displacement along y axis can be determined.

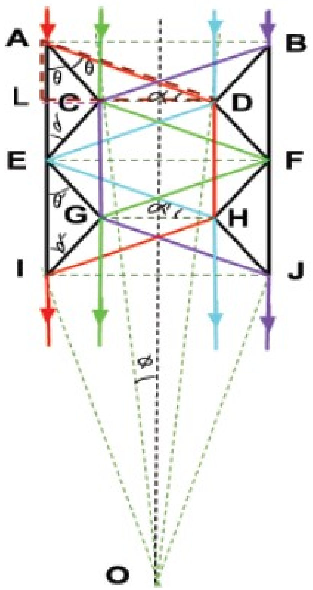
3. DISCUSSION AND CONCLUSION

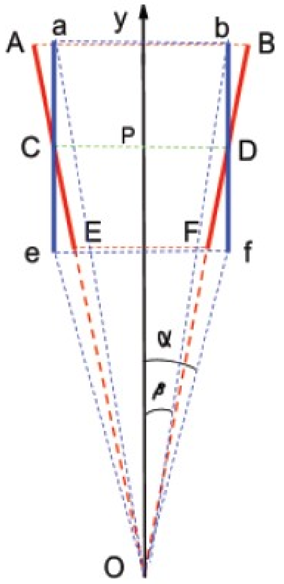
Three initial parameters ϕ, h and EF are reasonably decided by the concrete problem concerned. All the parameters and their relationships are definitely determined by the equations from (1) to (6); the area of 4 base triangles and isosceles trapezium by (7) and (8), respectively.

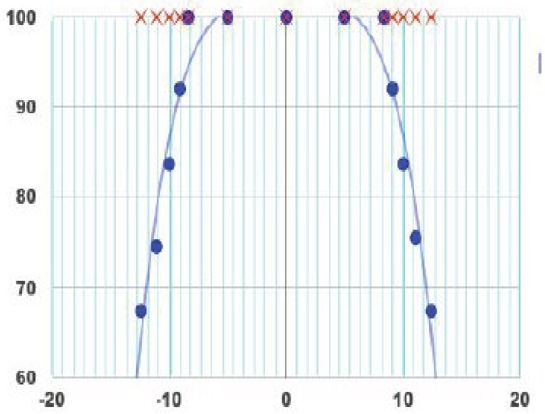
Both geometric intuition and strictly precise mathematical derivation enable us to get an interesting extrapolation, which is a limitation when separation between pillar and observer goes to infinity. In reality, the above separation never goes to infinity, therefore, such an extrapolation setup cannot be camouflaged perfectly. Two reasonable ideal models shown in Fig. 3, with all the parameters in Table 2, enable one to compare two such setups quantitatively with ease. Table 3 and figure 4 shows the invisibility rate with respect to flare angle and curves shown in Fig. 4 evidently indicate for both the quadrangular prism and its extrapolation set-up shifting from the most-clear observer point. The invisibility rate remains 100 percent for the quadrangular prism; conversely, for the extrapolation set-up, it goes down sharply when the flare angle bigger than 10 degrees. Further comparison are shown in Table 4 and the corresponding Fig. 5, which shows the invisibility rate of extrapolation is much less than that of quadrangular prism until the observer point moves to infinity. In addition to accurate mathematical proof, all the conclusions above are identical with the intuitive imagination.

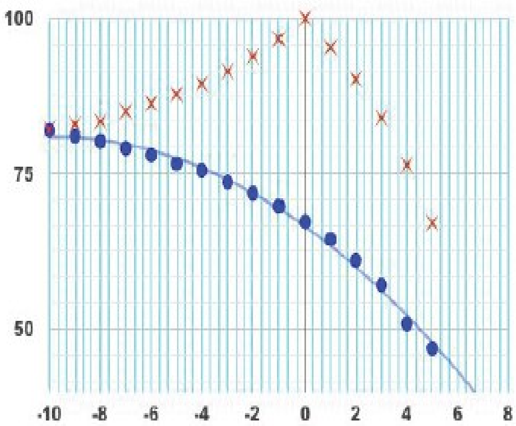
One of the applications of the quadrangular prism introduced here is to replace the traditional pillars to frame the windshield and side windows for all sorts of vehicles. Besides the invisible requirement, the mechanical intensity is an essential factor being considered. Based on the analyses above, it is easy for us to draw conclusions: the quadrangular prism of self-invisibility is a good possibility to replace traditional frames to support windscreen and glass windows being used widely in all kinds of vehicles and its invisibility rate is superior to the extrapolation which serves as an interesting deduction. In order to increase mechanical intensity, the space between two triangular prism systems shown in Fig. 1 should be filled with a certain soft transparent material.











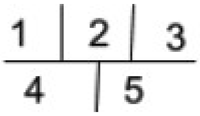


Fig.1 The sectional drawing of a quadrangular prism of self-invisibilitywith the light path indicating the invisible principle

Fig.2 An extrapolation derived from the quadrangular prism of self-invisibility with the light path indicating the invisible principle

Fig. 3 Two models for quadrangular prism (red line) and its extrapolation (blue line)

Fig.4 Comparison curves of invisibility rate of both a quadrangular prism (cross symbol)and its extrapolation (circle symbol) with respect to angular deviation

Fig. 5 Comparison curves of invisibility rate of both a quadrangular prism (cross symbol) and its extrapolation(circle) with respect to separation deviation

Table 1 The data determining a quadrangular prism

Initial condition 1	Initial condition 2	Initial condition 3	θ	δ	α
$\varphi = 5^o$	h = 1	EF = 4.00h	29.40^o	34.40^o	26.20^o
θ'	δ'	α'	S1 = Area of 2(ACE+EGI)	S2 = Area of ABJI	S1/S2 %
23.20^o	38.60^o	28.20^o	7.43	28.95	25.66%
A	B	C	D	E	F
(−2.28, 14.60)	(2.28, 14.60)	(−1.13, 12.92)	(1.13, 12.92)	(−2, 11.38)	(2.00, 11.38)
G	H	I	J		
(−0.80, 9.14)	(0.80, 9.14)	(−1.63, 7.20)	(1.63, 7.20)		

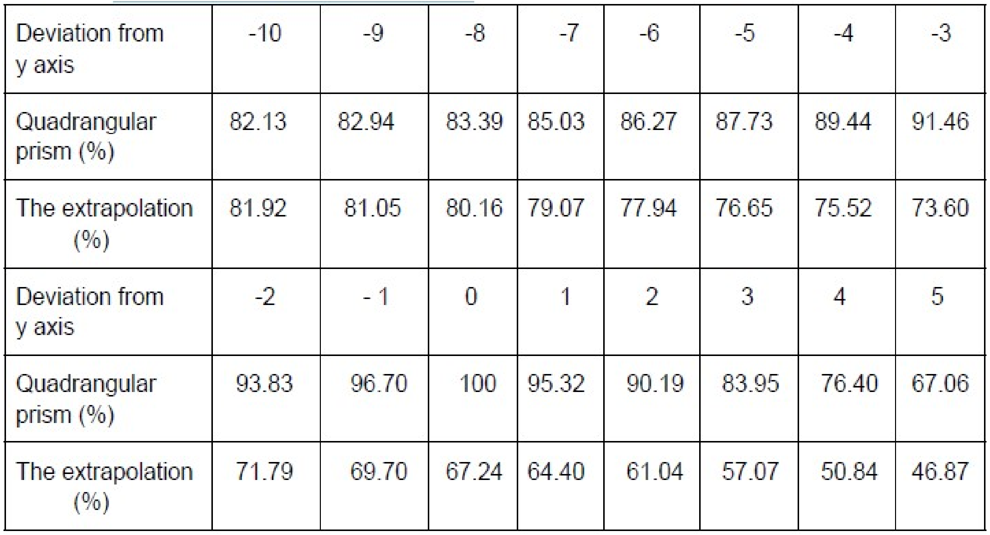
Table 2 The parameters depicting a quadrangular prism and its extrapolation

$\angle DOP$	$\angle bOP$	$\angle fOP$	ae,bf	AE,BF	CD
10^o	8.36^o	12.41^o	4	4	3.53
C	D	a	b	e	f
(-1.76,10.00)	(1.76,10.00)	(-1.76,12.00)	(1.76,12.00)	(-1.76,8.00)	(1.76,8.00)
A	B	E	F		
(-2.11,11.97)	(2.11,11.97)	(-1.42,8.03)	(1.42,8.03)		

Table 3 The invisibility rates of a quadrangular prism and its extrapolation with respect to angle deviation

Flare angle (degree)	-12.41	-11.06	-10.0	-9.09	-8.36	-5	0
Quadrangular prism	100%	100%	100%	100%	100%	100%	100%
The extrapolation	67.37%	75.59%	83.60%	91.96%	100%	100%	100%
Flare angle (degree)	5.00	8.36	9.09	10.00	11.06	12.41	
Quadrangular prism	100%	100%	100%	100%	100%	100%	
The extrapolation	100%	100%	91.96%	83.60%	75.59%	67.37%	

Table 4 The invisibility rates of a quadrangular prism and its extrapolation with respect to separation deviation



Deviation from y axis	-10	-9	-8	-7	-6	-5	-4	-3
Quadrangular prism (%)	82.13	82.94	83.39	85.03	86.27	87.73	89.44	91.46
The extrapolation (%)	81.92	81.05	80.16	79.07	77.94	76.65	75.52	73.60
Deviation from y axis	-2	- 1	0	1	2	3	4	5
Quadrangular prism (%)	93.83	96.70	100	95.32	90.19	83.95	76.40	67.06
The extrapolation (%)	71.79	69.70	67.24	64.40	61.04	57.07	50.84	46.87

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