Factor de Penalidad de Tags RFID Instalados en Vidrios de Vehículos

On-object Gain Penalty of RFID Tags Mounted on Car Glass

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RESUMEN

Este documento presenta un estudio sobre la identificación de los principales parámetros que intervienen en el factor de penalidad para Tags RFID cuando son instalados sobre el vidrio frontal de los vehículos. Evaluamos las cuatro variables con importancia relevante sobre este factor de penalidad: Tipo de vidrio, película polarizada, la polarización de la onda electromagnética, y el tipo de tag. La evaluación se realiza mediante pruebas experimentales basadas en la técnica de Diseño Experimental. A partir de los resultados, se logra obtener un modelo simplificado para determinar el factor de penalidad de acuerdo a las variables analizadas.

Palabras clave.- ANOVA, DOE, Factor de penalidad, Película polarizada, Penalidad de ganancia en objetos, RFID, TAG, Vidrio.

ABSTRACT

This paper presents a study on the identification of main parameters involved in the on-object gain penalty for RFID Tags when are used over front glass of vehicles. We assess four variables with relevant importance over this penalty: Glass type, polarized film, polarization of the electromagnetic wave, and the tag type. The assessment is performed using experimental tests based in the Design of Experiment technique. From the results, a simplified model to determine the on-object gain penalty is developed.

Key words.- ANOVA, DOE, Glass, On-object gain penalty, Penalty factor, Polarized film, RFID, Tag.

1. INTRODUCCION

Radio Frequency Identification (RFID) is a technology that allows the identification and track of an element using electromagnetic waves. An RFID based system is composed by three main elements: a reader, a tag and an application device or processing subsystem [1]. This technology has extended application fields such as inventory control, access control, and security.

RFID is regulated by the norm ISO/IEC 15962:2013 [2]. Typically, RFID works on three frequency bands: 125 KHz, 13.56 MHz, and 915 MHz. RFID applications that works on 915 MHz band are stablished by the standards EPC Global Gen2 or ISO/IEC 18000-6:2013 which are the most standards used on Intelligent Transportation System (ITS) due to their reading distance [3].

Preliminary studies performed by our research group showed that the installation of tags over front glasses of vehicles has a strong impact in the RFID reading range. This impact was studied by Griffin in [4], where the term on-object gain penalty is defined as:

$$\Theta = \frac{G_t}{G_{on\text{-}object}} \quad (1)$$

where Gt is the free space gain of the tag´s antenna and $G_{on\text{-}object}$ is the gain of the tag´s antenna attached to an object. Then, the on-object gain penalty represents the losses in the radio-link due to the change of the performance of the tag's antenna when is placed over an object [4].

This paper presents a study aimed to determine the variation of the antenna gain of tags when it is installed over an object. Using Design of Experiment (DOE), the effect of four factors on the on- object gain penalty was evaluated. The factors studied were the type of glass, the use of polarized films, the type of tag, and the film polarization, Table 1.

In order to present the study, this paper is organized as follows: In section two is shown the experimental setup that was built to data collection.

In section three, we show the measuring process and the technique used to find the on-object gain penalty to each experiment. In the fourth section, it is exposed the DOE and the ANOVA obtained. In the next section, it is presented a proposal of an approximated model

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***Table 1**. Factors used in the study.*

Factor	Levels	Vector	Levels
Polarized films	Without polarized film	Glass	Raw
			Laminate
	Graphite 5%		Tempered
	Graphite 35%	Tags	Paper tag
	Graphite 95%		Crystal tag
	Silver 0,22		Katherine tag
	Bronze mirror	Wave polarization	A
	Reflective		B

to determine the on-object gain penalty. Finally, in the sixth section the conclusions and recommendations are presented.

2. METHODOLOGY

The main interest of our study is to analyze the on-object gain penalty of RFID tags mounted on glass and tinted films. This parameter was characterized experimentally for different conditions in order to determine the factors that affect the operational properties of RFID tags. The experimental protocol was developed using the Design Of Experiment (DOE) technique.

Design Of Experiments (DOE) is a statistical technique that optimizes the experimental procedure and determines system performance with known input values. DOE evaluates all possible experimental variations and sets out factors that affect parameter under study. When the number of known input values is large, DOE sets the dominant variables and reduces the number of evaluations [5]. The type of study used here was full factorial, with 216 experiments. The studied factors are showed in the Table I and described in the next section.

Analyzed factors

1. Glass yype.- Three types of glass were considered.
   a) The Raw Glass: This is normal glass untreated.
   b) The Laminated Glass: This is a type of safety glass that holds together when shattered. If the glass is breaking, it is held in place by an interlayer of polyvinyl butyral (PVB) or ethylene-vinyl acetate (EVA) placed between the layers of glass. The interlayer keeps the layers of glass bonded even when broken and its high strength prevents the glass from breaking up into large sharp pieces. The lamminated glasses produce a characteristic "spider web" cracking pattern when the impact is not enough to completely pierce the glass.
   c) Tempered Glass: The tempered glass is processed by heat or chemical treatments to increase its hardness. The hardness of the glass causes no small sharp pieces when the glass breaks. This glass also prevents injury to passengers of a vehicle when it is broken.

2. Polarized films.- Polarized film is a material that selectively transmits some wavelengths of light. The six polarized films shown in the Table I were considered.
   a) Graphite Polarized Film: The graphite polarized films are characterized by the percentage of clarity allowed to pass. In this case, films of 5%, 35%, and 95% were considered. The case of a glass without polarized film was assumed as 100% of clarity.
   b) Other Polarized Films: Other considered polarized films such as silver 0.22, bronze mirror, and reflective are made with a special metal coating.

3. Tags type.- Three tags were considered.
   a) Tag 1 (ALN-9662): This is a general purpose tag used to itemize asset tracking, including: pallet placards, cases, baggage, poly bags, and electronics. This tag is designed to work well in challenging environments and its operation range is 840-960 MHz. This is a paper tag; for this reasons, is a low cost device [6].
   b) Tag 2 (ALN-9654): This is a tag used to identify high density plastic totes, windshields, batteries, and other elements. It is specially designed for use on glass. Its operation range is 840-960 MHZ [6].
   c) Tag 3 (52010220 WSL-T P-K-S): This tag is

mainly used in barrier control for cars parks, toll systems, and fleet management. Its operation frequency is 868 MHz and the typical and maximum reading range are 4 m and 8 m, respectivelly [7].

4. Wave polarization.- Two orientations of the films whit repect to the polarization of the interrogation incident wave were considered. This factor was taken into account to rule out possible effects on the on-object penalty due to the manufacture of the polarizing film.

3. MEASURING PROCESS AND DATA ANALYSIS TECHNIQUE

On-object gain penalty

The equation 1 is the definition of the on-object gain penalty. If equation 1 is used, two antenna gains should be measured. In this case, tags should be altered removing the chip and connecting a RF source with a known power. This tag intervention can alter the antennas and produce erroneous data collection. Other procedure to get the on-object gain penalty was developed using the tag received power equation described by Griffin in [4] as:

$$P_R = \frac{P_T G_R G_T G_t^2 \lambda^4 X_f X_b M}{(4\pi)^4 r_f^2 r_b^2 \Theta^2 B_f B_b F_b} \quad (2)$$

where P_R is the receiver modulated backscattered power, r_f is the reader-to-tag link separation distance [m], r_b is the tag-to-reader link separation distance [m], X_f is the reader-to-tag link polarization mismatch, X_b is the tag-to-reader link polarization mismatch, B_f is the reader-to-tag link path-blockage loss, B_b is the tag-to reader link path-blockage loss, and F_β is the bistatic

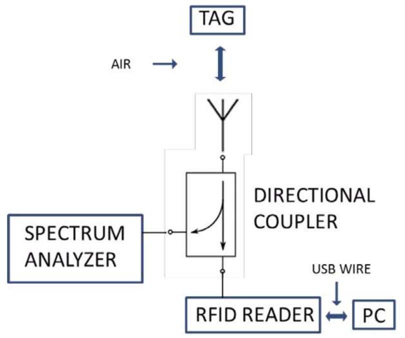

Figure 2. Measuring process for calculate error.

dislocated small-scale fading loss. This equation can be rewritten on logarithmic form as:

$$P_R dB = AdB - 20\log(\Theta) \quad (3)$$

Where AdB is a constant of the link parameters different to Θ in equation 2 are not modified. If the tag is not over an object, equation 3 can be written without the term 20log (Θ).

If we can ensure that AdB is not altered during the data collection, this value can be used as a reference power (P_r) since it corresponds to the received power when the tag is not over an object. Using this reference and the measured on-object tag power (P_R), we can solve Θ from (3) as:

$$\Theta = 10^{\frac{P_r dB - P_R dB}{20}} \quad (4)$$

The received signal strength indicator (RSSI) reported by a reader Impinj Multireader Speedway Revolution

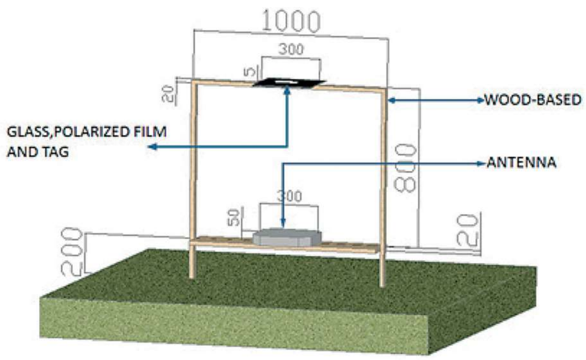

Figure 1. Experimental setup.

***Table 2**. Readings obtained for the tag 1 in dBm.*

TAG 1							
		POLARIZATION A			POLARIZATION B		
	Without	**Raw**	**Lam.**	**Temp.**	**Raw**	**Lam.**	**Temp.**
Without polarized film	-46,44	-68,61	-60,57	-63,74	-58,15	-60,51	-57,99
	-46,31	-68,25	-60,59	-63,67	-58,14	-60,49	-58,01
	-46,53	-68,35	-60,52	-63,71	-58,17	-60,46	-58,01
Graphite 5%	X	-68,06	-65,68	-65,36	-44,38	-63,18	-59,54
	X	-68,08	-65,56	-65,35	-44,44	-63,20	-59,69
	X	-68,14	-65,75	-65,30	-44,52	-63,21	-59,63
Graphite 35%	X	-71,11	-68,57	-67,15	-69,20	-73,47	-69,41
	X	-70,95	-68,71	-67,02	-69,21	-73,72	-69,09
	X	-70,67	-68,55	-67,42	-69,30	-73,88	-69,16
Graphite 95%	X	-68,63	-62,13	-54,62	-69,47	-69,36	-69,21
	X	-68,83	-62,17	-54,60	-69,01	-69,42	-69,22
	X	-68,79	-62,13	-54,43	-68,95	-69,28	-69,14

***Table 3**.* Readings obtained for the tag 2 in dBm.

TAG 2							
		POLARIZATION A			POLARIZATION B		
	Without	**Raw**	**Lam.**	**Temp.**	**Raw**	**Lam.**	**Temp.**
Without polarized film	-46,19	-43,80	-42,87	-47,61	-40,66	-40,30	-40,01
	-46,22	-43,75	-42,90	-47,73	-40,50	-40,34	-40,17
	-46,25	-43,78	-42,94	-47,68	-40,68	-40,41	-40
Graphite 5%	X	-42,79	-42,65	-43,19	-45,61	-43,76	-42,46
	X	-42,81	-42,75	-43,19	-45,6	-43,87	-42,44
	X	-42,86	-42,57	-43,13	-45,57	-43,91	-42,52
Graphite 35%	X	-46,82	-43,30	-44,85	-45,33	-45,63	-42,81
	X	-46,91	-43,31	-44,98	-45,41	-45,72	-42,86
	X	-46,92	-43,35	-44,76	-45,37	-45,67	-42,88
Graphite 95%	X	-44,93	-43,37	-44,19	-44,38	-46,62	-48,13
	X	-45,22	-43,54	-44,14	-44,44	-46,66	-48,35
	X	-45,22	-43,46	-44,15	-44,52	-46,63	-47,98

***Table 4**. Readings obtained for the tag 3 in dBm.*

TAG 3							
		POLARIZATION A			POLARIZATION B		
	Without	**Raw**	**Lam.**	**Temp.**	**Raw**	**Lam.**	**Temp.**
Without polarized film	-54,19	-51,02	-50,94	-50,99	-47,79	-48,09	-47,54
	-54,13	-51,04	-50,70	-50,91	-47,91	-47,17	-47,33
	-54,24	-51,07	-50,59	-51	-47,76	-47,15	-47,29
Graphite 5%	X	-54,54	-51,09	-53,44	-55,97	-55,04	-57,65
	X	-54,64	-51,08	-53,43	-56,02	-54,76	-57,62
	X	-54,64	-51,26	-53,45	-56,06	-55,05	-57,62
Graphite 35%	X	-57,48	-53,52	-74,89	-50,01	-49,73	-50,89
	X	-57,47	-53,68	-74,57	-50,15	-49,77	-50,80
	X	-57,41	-53,59	-74,27	-50,18	-49,82	-50,92
Graphite 95%	X	-54,03	-62,42	-52,07	-57,17	-56,07	-59,17
	X	-54,13	-62,14	-52,07	-57,31	-56,05	-59,28
	X	-54,20	-62,15	-52,16	-57,28	-56,14	-59,28

Table 5. On-object gain penalty tag 1.

		TAG 1					
		POLARIZATION A			POLARIZATION B		
	Pr (dBm)	Raw	Lam.	Temp.	Raw	Lam.	Temp.
Without polarized film	-46,44	12,85	5,10	7,34	3,86	5,06	3,79
	-46,31	12,33	5,11	7,28	3,85	5,05	3,80
	-46,54	12,48	5,07	7,32	3,86	5,03	3,79
Graphite 5%	X	12,07	9,18	8,85	0,79	6,88	4,53
	X	12,10	9,05	8,83	0,80	6,90	4,60
	X	12,18	9,25	8,78	0,80	6,91	4,58
Graphite 35%	X	17,14	12,80	10,87	13,77	22,51	14,10
	X	16,84	13,01	10,70	13,77	23,17	13,59
	X	16,29	12,77	11,21	13,92	23,60	13,70
Graphite 95%	X	12,89	6,10	2,57	14,21	14,03	13,77
	X	13,19	6,13	2,56	13,47	14,11	13,80
	X	13,13	6,10	2,51	13,38	13,88	13,66

was used to get the power received from the Tag. The RSSI was compared with the values measured in a Spectrum Analyzer (SA) to validate the measurements using the experimental setup shown in Fig. 2. The evaluation parameter was the absolute error between the SA and the Reader measurement. Since a difference lower than 1 dB was obtained, it was concluded that the RSSI provides power values with enough accuracy for our test.

Experimental Setup

The wood-based structure shown in fig. 1 was constructed to perform the test. The structure had a vertical configuration to avoid the reflected waves from the floor. It was constructed and assembled without any conductor material to avoid internal reflected waves. The structure was designed to fit with two different antennas connected to the RFID reader: a Yagi and a circular polarized patch. The experiment was thought for work on the far field of the antennas. The far field of the Yagi antenna was calculated over two meters, while the far field for the patch antenna 76 cm. So, the structure height was defined by the Yagi antenna far field. Some special items were implemented such as: a glass and tags support, a system to change the structure height and a module to insert and adjust each antenna type.

4. RESULTS

The measurements obtained with the Yagi antenna did not give satisfactory results because in some cases no measurement was obtained. Therefore the analysis was performed with the circular polarized antenna. The Tables 2, 3 y 4, show the obtained power readings for the each tag.

Table 6. *On-object gain penalty tag 2.*

		TAG 2					
		POLARIZATION A			POLARIZATION B		
	Pr (dBm)	**Raw**	**Lam.**	**Temp.**	**Raw**	**Lam.**	**Temp.**
Without polarized film	-46,19	0,76	0,68	1,17	0,53	0,51	0,49
	-46,22	0,75	0,68	1,19	0,52	0,51	0,50
	-46,26	0,76	0,69	1,18	0,53	0,51	0,49
Graphite 5%	X	0,67	0,66	0,71	0,93	0,75	0,65
	X	0,68	0,67	0,71	0,93	0,76	0,65
	X	0,68	0,66	0,70	0,93	0,77	0,65
Graphite 35%	X	1,07	0,71	0,85	0,90	0,93	0,68
	X	1,08	0,71	0,87	0,91	0,94	0,68
	X	1,08	0,72	0,85	0,91	0,94	0,68
Graphite 95%	X	0,86	0,72	0,79	0,81	1,05	1,25
	X	0,89	0,73	0,79	0,81	1,05	1,28
	X	0,89	0,73	0,79	0,82	1,05	1,23

The Table 2 shows that the tag 1 with a tempered glass, polarization A, and 95% graphite polarized film is the best case, because it presents the higher received power. On the other case, the laminated glass, with polarization B, and 35% graphite polarized film is the worst case.

The Table 3 shows that the tag 2 with a tempered glass, polarization B, and without polarized film is the best case and the tempered glass, with polarization B, and 95% graphite polarized film is the worst case.

The Table 4 shows that the tag 3 with a tempered glass, polarization B, and without polarized film is the best case, while the tempered glass, with polarization A, and 35% graphite polarized film is the worst case. From the Tables 1, 2 y 3, the experiment shows that the tag 2 has the best performance. It is worth noting that this tag is specially designed for glass as mentioned above.

The Tables 5, 6 y 7 present the on-object penalty calculated using (4). P_r was taken as the received power by the reader from the tag, without polarized film and without glass. These tables show the difference of the performance of a tag designed for a glass (tags 2 and 3) and a general purpose tag (tag 1).

The on-object gain penalty for a specially designed tag is lower than for most of cases, showing an improvement in the antenna gain when the tag is placed over the glass. On the other side, the general purpose tag produced penalties higher than 20, which represents 13 dB of losses.

***Table 7**. On-object gain penalty tag 3.*

		TAG 3					
		POLARIZATION A			POLARIZATION B		
	Pr (dBm)	**Raw**	**Lam.**	**Temp.**	**Raw**	**Lam.**	**Temp.**
Without polarized film	-54,20	0,69	0,69	0,69	0,48	0,50	0,47
	-54,13	0,70	0,67	0,69	0,49	0,45	0,45
	-54,25	0,70	0,66	0,69	0,48	0,44	0,45
Graphite 5%	X	1,04	0,70	0,92	1,23	1,10	1,49
	X	1,05	0,70	0,92	1,23	1,07	1,48
	X	1,05	0,71	0,92	1,24	1,10	1,48
Graphite 35%	X	1,46	0,93	10,84	0,62	0,60	0,68
	X	1,46	0,94	10,46	0,63	0,60	0,68
	X	1,45	0,93	10,10	0,63	0,60	0,69
Graphite 95%	X	0,98	2,58	0,78	1,41	1,24	1,77
	X	0,99	2,50	0,78	1,43	1,24	1,80
	X	1,00	2,50	0,79	1,43	1,25	1,80

***Table 8.** Anova to the experiment.*

	2 Source	3 Sum of Squares	4 DF	5 Mean Square	6 F Value	7 Prob > F	8 % Contribtn
1	**Model**	4946,15	31	159,55	32,85	< 0.0001	
2	**A**	8,84	2	4,42	0,91	0.4045	0,15
3	**B**	438,91	3	146,30	30,12	< 0.0001	7,52
4	**C**	4,81	1	4,81	0,99	0.3207	0,08
5	**D**	3621,14	2	1810,57	372,75	< 0.0001	62,01
6	**AB**	34,20	6	5,70	1,17	0.3223	0,59
7	**AC**	89,67	2	44,84	9,23	0.0002	1,54
8	**AD**	105,72	4	26,43	5,44	0.0004	1,81
9	**BC**	143,41	3	47,80	9,84	< 0.0001	2,46
10	**BD**	490,96	6	81,83	16,85	< 0.0001	8,41
11	**CD**	8,49	2	4,25	0,87	0.4189	0,15
12	**Residual**	893,75	184	4,86			
13	**Lack of Fit**	891,49	40	22,29	1418,57	< 0.0001	
14	**Pure Error**	2,26	144	0,02			
15	**Cor Total**	5839,90	215				

5. RESULTS ANALYSIS

Influence factors

Notice that the presented results do not include metallized films.

This is because the silver 0.22, bronze mirror, and reflective polarized films completely shielded the interrogation signal and no readings were obtained. These films are mainly made of conductive materials, therefore, the study focused on the analysis of polarized graphite films.

The results of the full factorial DOE are shown in Table 8. The factors in the table are named as follows: A is the glass type, B is the polarized film type, C is wave polarization, and D is the tag number.

The sum of squares is the sum of differences between the response values and the sample mean. It represents the total variation in the response values. DF is the degrees of freedom associated with each source or variation thereof. Mean Square is the lists of the mean squares. Each Mean Square is the sum of squares divided by its corresponding DF. The F Value or F ratio shows whether the model is significantly predictable considering the regression framework.

The value Prob> F gives the probability value for the test. This value sets how likely the occurrence of F in the experiment. And % Contribution is the percent of contribution of each variable in the experiment. The Table 8 shows that the higher contribution is due to the tag type, followed by associating between type polarized film, and the tag type. On the other hand, the table reveals that the glass type and the polarization of the wave have little effect on the on-object gain penalty.

On-object gain penalty model

Polynomial equations used on DOE, does not allow describing the behavior of the penalty phenomenon. Thus, a model where the polarized films and the tags coupling introduce losses is more adequate. In this case we can define:

$$\Theta = f(g) \cdot \tau \tag{5}$$

where τ is a tag coupling factor, which is a fixed value for each tag. This factor depends on the coupling capacity between the tag and the glass. And f(g) is a function of the polarized film graphite percent, g. Since different tags and different graphite percent levels were characterized, different values of Θ were measured. The average values for each case are presented in the left side of (6). Applying (5), the Θ matrix can be equated to the product between the vectors f(g) and τ.

The four row of the F vector corresponds to the polarization films analyzed in the experiment. The three columns of the T vector correspond to the tag coupling factors of the three characterized tags.

Using the non-negative factorization function in Matlab, the approximate values for f(g) and T were calculated in (6) and (7).

Finally, to obtain Θ as a function of τ and g, the obtained values of τ were replaced in (5) and the function that best fitted over the experimental data was deduced. Therefore, the following expression was obtained:

$$\Theta = 10^{-\left(\frac{g-0.54}{0.76}\right)^2 + 1.25} \cdot \tau \tag{8}$$

Where Θ is the on-object gain penalty, g is the graphite percent on the polarized film for each film. And τ is

$$\Theta = \begin{bmatrix} 7.05 & 0.73 & 0.08 \\ 15.21 & 0.86 & 0.46 \\ 10.52 & 0.91 & 0.46 \\ 6.27 & 0.69 & 0.57 \end{bmatrix} = \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix} \begin{bmatrix} T_1 & T_2 & T_3 \end{bmatrix} \tag{6}$$

$$\begin{gathered} \begin{bmatrix} T_1 & T_2 & T_3 \end{bmatrix} = \begin{bmatrix} 0.99 & 0.07 & 0.03 \end{bmatrix} \\ \begin{bmatrix} F_1 & F_2 & F_3 & F_4 \end{bmatrix} = \begin{bmatrix} 7.08 & 15.23 & 10.56 & 6.32 \end{bmatrix} \end{gathered} \tag{7}$$

the tag coupling factor for each tag. The error of 6 is lower than 2dB.

6.CONCLUSIONS

During the experiment, it was observed that the type of glass or orientation have not influenced the on-object gain penalty. However, the tag type greatly affects the on-object gain penalty. For this reason, tags designed for glass are strongly recommended for vehicle identification. This kind of tags presents a good coupling with any glass type, obtaining small values of on-object gain penalty.

An on-object gain penalty model was developed based on the DOE results. This model presented an adequate accuracy. In addition, the model only requires two parameters, corresponding to the τ factor, which depends on the tag, and the polarized film graphite percent.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and support of Angélica Parra and Johan Henao in the elaboration of this paper.

This work was developed under the research project "Plataforma para el control inteligente de vehículos PCIV" (Hermes code: 20097) and financially supported by the Ministry of Transport of Colombia under the contract No. 0654-2013 granted by the Colciencias call No. 622-2013.

REFERENCES

1. Dong-liang, W., Wing, W. Y, Daniel S. Yeung, Hai-Lan Ding, "A brief survey on current rfid applications", in Proc. 2009 Proceedings of the Eighth International Conference on Machine Learning and Cybernetics, Boading, pp. 2330-2335.
2. ISO/IEC, "ISO/IEC 15962:2013 "Information technology - Radio frequency identification (RFID) for item management" - Data protocol: data encoding rules and logical memory functions," 2004.
3. ISO/IEC, "ISO/IEC 18000-6:2013 "Information technology -- Radio frequency identification for item management" - Part 6: Parameters for air interface communications at 860 MHz to 960 MHz General, " 2004.
4. Joshua D. Griffin., Gregory D. Dirgin., "Complete Link Budgets for Backscatter-Radio and RFID Systems," in Proc. 2009 IEEE Antennas and Propagation Magazine., vol. 51, no. 2, pp. 11-25, April 2009.
5. Manny Uy., J. K. Telford, "Optimization by Design of Experiment Techniques," Baltimore, Maryland, Johns Hopkins University.
6. Alien Technology LLC, Alien Family of EPC Gen 2 RFID Inlays, Morgan Hill, 2015.
7. Kathrein RFID, RFID-UHF-Products 2015, Kronstaudener Weg 1, D-83071 Stephanskirchen, 2015.