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RFID Tag for Railway Applications Based on Narrow-Band Absorbers

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ABSTRACT

A novel design of a new passive tag RFID for railway application is presented. The proposed tag is based on multi-section narrow-band absorbing tiles. Based on absorbing resonance frequencies, different digits of the proposed RFID system are obtained. Thus the presence of an absorbing tile with specific resonance frequency corresponds to '1' at the corresponding digit while replacing this tile with PEC sheet corresponds to '0' at this digit. The proposed RFID system is based on UWB frequency band from 3.3 to 11.3 GHz. This band is divided into eighteen frequencies which correspond to eighteen digits. Designs of narrow band absorbers at these frequencies are presented in this paper. These designs should have appropriate bandwidth to avoid interference between closed digits as well as the Doppler Effect due to the speed of the railway vehicle. The proposed designs are based on using lossy substrates with low conductive patches. Radar cross sections (RCS) of finite tiles of these narrow band absorbers are presented. The difference between the RCS of the absorber tile and the equivalent PEC tile corresponds to the difference between '1' and '0' at the corresponding digit.

***Keywords**: RFID Tag, Absorbers, RCS, Periodic structures.*

I. INTRODUCTION

Radio frequency identification (RFID) is a wireless communication technology that is used to uniquely identify tagged objects for both moving and stationary cases. It has many applications like livestock management, pharmaceutical industry, medical applications ... etc. Vehicle identification is another important application for RFID system. In this case the tagged object should be suitable to be identified at both stationary and moving cases. This makes the design of RFID for vehicle identification is more complicated [1, 2]. One of the important vehicle identification systems is railway identification. Railway identification could be simpler than other vehicle identifications like cars and trucks because in railway system the vehicles are constrained by the railway path only. This property simplifies the design of RFID system for railway application from the point of locating the reader with respect to the expected location of the tag. However, the main problem in the RFID system for railway application is the wide range of expected speed between the reader and the tag. In the station the speed may be zero, however, in the case of maximum speed it may be more than 140 km/h (In Egypt). Much more values of speed are available too. This high speed introduces critical issue in the reading time of the moving tag. In addition, it introduces Doppler Effect. These two parameters represent main criteria to design a RFID system for railway applications [3].

The RFID system consists of three elements; RFID Tag, RFID reader and database. The RFID tag element consists of an antenna integrated with a microchip. The RFID reader and antenna transmit an electromagnetic RF signal. This signal is received by the RFID tag via the tag's antenna. The energy in the received signal provides the power to the tag that allows the microchip to operate. This is referred to as a "passive" tag. This data from the microchip is then added to an RF signal that is "reflected" by the tag back to the reader through the reader antenna. This process is referred to as passive backscatter. The reader contains the electronics to receive this signal from the tag, extract the RFID tag's code from the signal, and return it to its digital form, and provide that returned code to a host computer.

RFID systems are classified into two main categories; passive and active. In active RFID system the tag is equipped with active circuits which are powered by an internal source or by converting the reading signal to power signal. In railway application, where the vehicle is expected to be moving with fast speed, this power signal can be obtained by induction effect between a coil fixed on the vehicle and a stationary permanent magnet fixed in advance to the location of the reader [4]. However, this system is not suitable if the vehicle is stationary or moving at slow speed. Active RFID systems are usually quite sensitive due to their electronics parts. This makes active RFID system may not be suitable for railway environment where the tag is usually mounted on the outside parts of the vehicle where it may not be suitably protected. On the other hand, passive RFID systems are based on modifying the backscattered electromagnetic wave from the tag. This can be obtained by using multi resonators [5]. These multi resonators may be coupled to two antennas with orthogonal polarizations as receiving and transmitting antennas. The reader in this case is composed of a wideband source feeding a wideband antenna. The notches in the spectrum of the backscattered field in this case represent the digits of the identification signals. This configuration is quite suitable for the case of stationary target. However, at high speed, the available reading time when the tag passes by the reader may not be sufficient for the reading circuit. Thus, it would be required develop another technique to introduce these notches in the backscattered field at a larger area. This can be done by replacing the resonators by narrow band absorbing tiles as shown in Fig. 1. These absorbing tiles are similar to the black lines in the normal barcode identification system. However, conventional barcode is based on using narrow laser beam as a reader. This laser beam is usually very narrow band but in this paper wide band from 3.3 to 10.3 GHz is proposed. This is equivalent to a colorful barcode as every color corresponds to a certain frequency to express this bit.

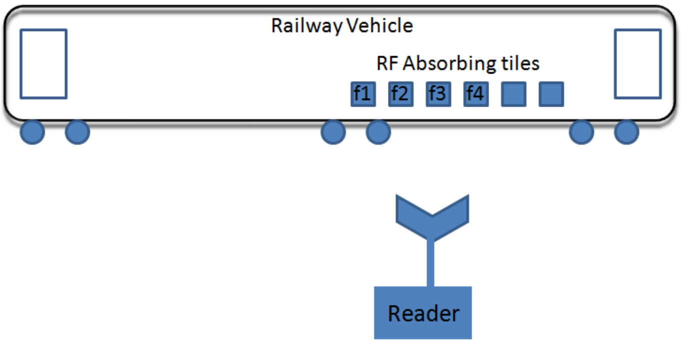
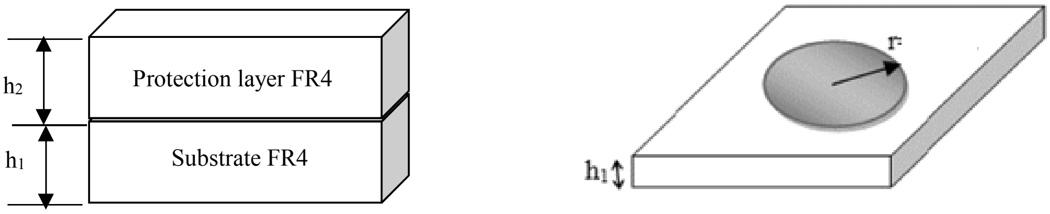


Fig. 1: Schematic diagram of the proposed passive RFID system for railway vehicles based on Narrow band absorbing tiles

Electromagnetic absorbing materials can be obtained by using artificial electromagnetic materials like grounded dielectric slab loaded by periodic patches. The main advantage of this configuration is that it is usually thinner than conventional absorbing sheets based on embedded absorbing materials like pyramidal absorbers [7,8]. However, the main disadvantage of these artificial absorbers is that they are usually narrow band. This disadvantage as an absorber is quite important as an RFID tag. However, this narrow band should be enough to include the Doppler Effect for the case of high speed RFID tag. The main idea of using narrow band absorbers as RFID tags is based on using different absorbing frequencies as different digits. The purpose of this paper is to present designs of different narrow band absorbers to be used as separate tiles for RFID tag of a railway vehicle based on multilayered thin periodic structures. In Sec. II, the designs of the unit cell of these absorbers are presented. In Sec. III, the RCS of finite tiles of these absorbers are compared with the corresponding RCS of PEC tile of the same size. This difference corresponds to the difference between the ‘1’ state and the ‘0’ sate at the corresponding digit to this absorbing frequency. The numerical simulation obtained by (high frequency structural simulator) HFSS 13.

II. DESIGN OF NARROW BAND ABSORBERS

Artificial absorbers can be obtained by periodic structures on lossy substrate. The design of artificial absorbers is based on four main parameters specifically, the substrate parameters, the shape of the printed patches, the shape of the periodic cell and the material of the printed patches. These parameters are used to control the absorption frequency and the value of wave absorption. The substrate is assumed to be a grounded FR-4 slab with relative dielectric constant 4.5 and loss tangent 0.019. The thickness of the substrate is 3.2 mm. The printed patches are composed of low conductive paste based on conjugated polymer and polyurethane binder of conductivity about 3400 S/m. The small conductivity of this conductive paste plays an important role in the absorption mechanism. The thickness of the patch is nearly 20 μm. The dimensions of the unit cell and the patch depend on the required absorbing frequency. In addition, another dielectric layer is added as a superstrate. This superstrate is important in the proposed application to protect the patch from the surrounding environment in the railway application. The superstrate is also FR-4 like the substrate but the thickness is assumed to be 1.6 mm. The unit cell of the periodic structure is assumed to be square and the patch is assumed to be circular shape as shown in Fig. 2.



(a) Substrate-superstrate structure *(b) Shape of the printed patch*

Fig. 2: Geometry of the unit cell

The proposed frequency band is conventional UWB from 3.3 to 10.3 GHz. The reader antenna is assumed to be UWB antenna which is used to transmit almost the entire bandwidth of UWB signal. The absorbers are assumed to be digitized at eighteen steps from 3.3 to 10.3 GHz. The length of the square unit cell and the diameter of the printed patch correspond to the design parameters of these absorbers. Simulation of an infinite array of this unit cell can be obtained numerically by using periodic boundary conditions. These periodic boundary conditions can be resembled for normally incident plane wave by using image theory as two parallel PEC boundaries combined with other two parallel PMC boundaries. Excitation of this configuration is obtained by using a wave-port with electric field parallel to the PMC walls.

Table 1 presents the obtained dimensions of the cell size and patch diameter for the proposed frequencies. Figure 3 shows the reflection coefficient of an infinite array for sample of these frequencies. According to the simulation results of reflection loss, the designed unit cell circular patch had a minimum loss of -36 dB at the resonance frequency 6.3 GHz, meaning that over 90 % of incident energy was absorbed. The -10 dB bandwidth was almost 0.33 GHz (6.17 to 6.5 GHz), as shown in Fig. 3.

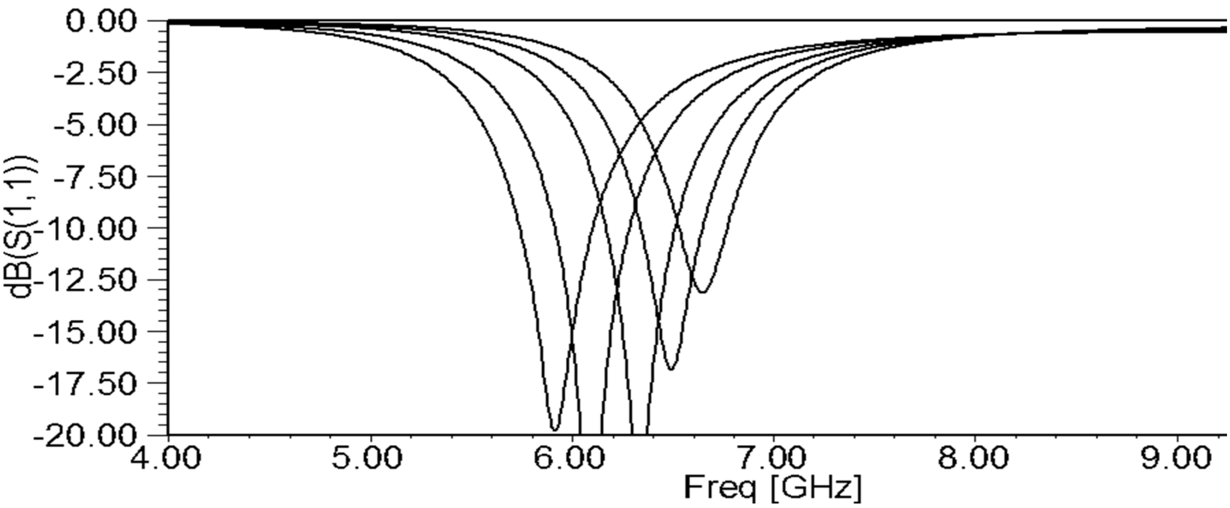


Fig. 3: Reflection coefficients for samples of designed infinite array absorbers

Table 1: Dimensions of unit cells for narrow band absorbers at different resonance frequencies

Bit #	*Freq.* (GHz)	*L(mm)*	*r(mm)*
1	3.5	12	5
2	3.9	11.5	4.75
3	4.3	11	4.5
4	4.7	10.5	4.25
5	5.1	10	4
6	5.5	9.5	3.75
7	5.9	9	3.5
8	6.3	8.5	3.25
9	6.7	8	3
10	7.1	7.5	2.75
11	7.5	7	2.5
12	7.9	6.5	2.25
13	8.3	6	2
14	8.7	5.5	2
15	9.1	5	2
16	9.5	4.5	1.75
17	9.9	4.2	1.6
18	10.4	4	1.5

It should be noted that Doppler effect at maximum operating frequency is nearly 2 kHz for a vehicle moving with a speed about 200 km/h. Thu, the obtained bandwidth as shown in Fig. 3 is much more enough for including this Doppler effect.

III. RADAR CROSS SECTION OF FINITE ABSORBING TILES

In the previous section, reflection coefficient of an infinite array absorbing structure is discussed. However, in practical case, just finite tiles of these absorbers are used. In this case, the results of infinite array represent only qualitative indication of the behavior of the tile. However, the design of the identification system for the proposed RFID system requires accurate prediction for the back reflected signal for the case of the absorbing tile compared with conventional PEC tile. Thus, in practical case it would be required to determine the difference between the RCS of absorbing tile and the corresponding PEC tile. The finite tiles are assumed to be square shapes of length 16 cm as shown in Fig. 4. The cells on the tiles are obtained by infinite periodic approximation as discussed in Section II.

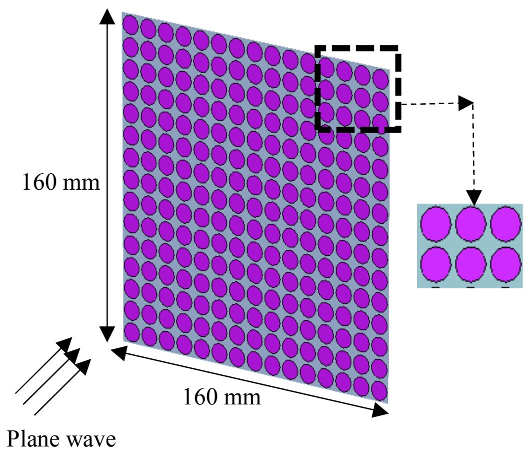


Fig. 4: Finite tile of absorber.

Figure 5 shows a comparison between the bistatic RCS of a PEC tile and an absorbing tile designed at resonance frequency 6.3 GHz. The result in Fig. 5 is normalized to the peak scattering of the PEC. It can be noted that at broadside direction the difference between RCS of the absorbing tile and the corresponding PEC tile is more than 10 dB. This difference is quite enough to the reader to discriminate between the state '1' and the state '0' at this digit. Figure 6 shows the above comparison for all required frequency points for broadside direction where $\theta_i = \theta_r = 0$. It can be noted that the difference between RCS of the absorbing tiles and the corresponding PEC tiles is close to 10 dB in all bands. However, this difference slightly decreases at higher frequencies, but it is still enough to the reader to discriminate between the state '1' and the state '0'.

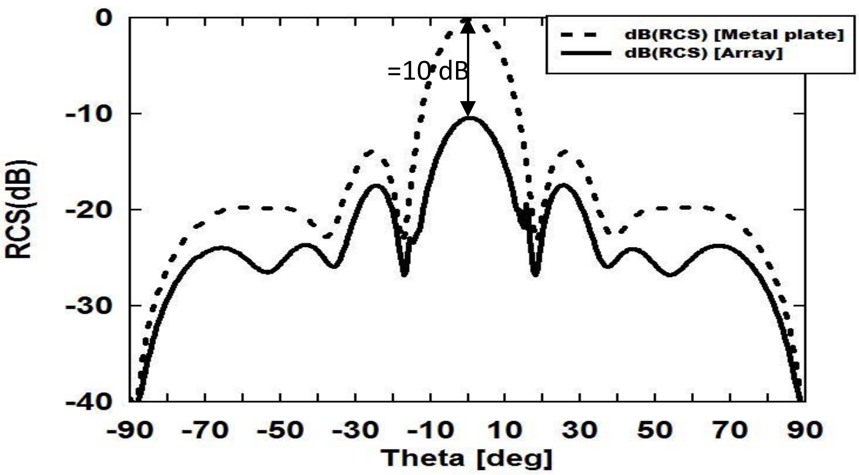


Fig. 5: A comparison between the bistatic RCS of a PEC tile and an absorbing tile designed at resonance frequency 6 GHz

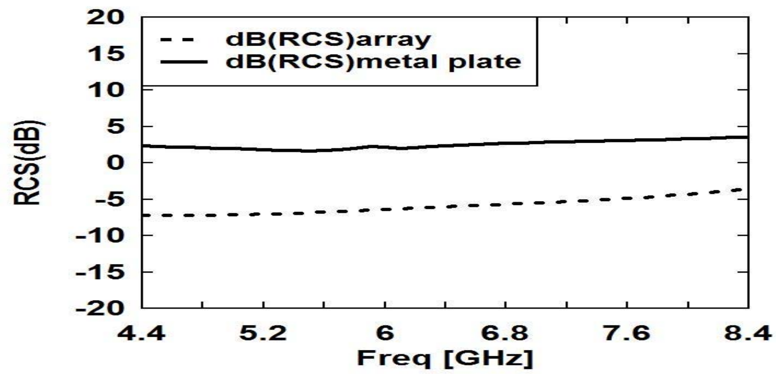


Fig. 6: A comparison between the bistatic RCS of a PEC tile and an absorbing tile designed at resonance frequency 6.3 GHz.

IV.CONCLUSION

A new idea for using narrow band absorbers as RFID tag for railway vehicles is presented. Analysis and design of different narrow band absorbers at discrete frequency points in the frequency band from 3.3 GHz to 10.3 GHz are discussed in detail. The proposed structures are composed of periodic circular patches of lossy polymer printed on a grounded FR-4 substrate and covered by another superstrate as a protection layer. The dimensions of the unit cell and the radius of the patches are obtained for the assigned frequencies based on infinite array approximation. Then the RCS of finite absorbing tiles of the designed cells are compared with the corresponding RCS of a PEC tile. The size of the tile is 16 x 16 cm^2. It is found that the differences between the RCS of the absorbing tile and the PEC tiles are around 10 dB for the designed frequencies. This difference is quite enough to be discriminated between the digital states at the corresponding frequency of the tile.

References

[1] Qiu Jinghui Sun Bo You Qidi, "Study on RFID Antenna for Railway Vehicle Identification", 6th International Conference on ITS Telecommunications Proceedings, 2006.

[2]A.A.Pandit, Jyot Talreja, Ankit Kumar Mundra, "RFID tracking system for vehicles (RTSV)", First International Conference on Computational Intelligence, Communication Systems and Networks, 2009.

[3] Xiaoqiang Zhang, Vasileios Lakafosis, Anya Traille and Manos M. Tentzeris, "Performance Analysis of Fast-Moving RFID Tags in State-of-the-Art High-speed Railway Systems", IEEE International Conference on RFID-Technology and Applications, 17 - 19 June Guangzhou, China, 2010.

[4] Md. Aminul Islam, Yixian Yap, Nemai Karmakar and A K M Azad, "Orientation Independent Compact Chipless RFID Tag", IEEE International Conference on RFID -Technologies and Applications (RFID - TA) 2012.

[5] Y. F. Weng, S. W. Cheung, T. I. Yuk, and L. Liu, "Design of chipless UWB RFID system using a CPW multi-resonator", IEEE Antennas and Propagation Magazine, vol. 55, no. 1,pp 78-82, February 2013.

[6] STEPHEN B. MILES, SANJAY E. SARMA, JOHN R. WILLIAMS, "RFID Technology and Applications", Cambridge University Press 2008.

[7] J. Reinert, J. Psilopoulos, J. Grubert, and A. F. Jacob, "On the potential of graded-chiral Dallenbach absorbers," *Microwave and Optical Technology Letters*, vol. 30, no. 4, pp. 254-257, 2001.

[8] F. Terracher, G. Berginc, "A broadband dielectric microwave absorber with periodic matallizations," Journal of Electromagnetic Waves and *Applications,* Vol. 13, pp. 1725–1741, 1999.

[9] N. Engheta, "Thin absorbing screens using metamaterial surfaces," in 2002 IEEE International Symposium on Antennas and Propagation, San Antonio, TX, Vol. 2, pp. 392-395, 2002.

[10] John Huang, Jose Antonio Encinar, "Reflect array antenna", John Wiley & Sons, 2007

[11] E. F. Knott, J. F. Shaeffer, M. T. Tuley, *Radar Cross Section*, Artech House London, 1993.