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Analysis of impacts on the change of frequency band for RFID system in Brazil

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***Abstract*—With the proposal to implement a high-speed train in Brazil, the frequency range of 5.5 MHz (in 902 MHz) will be used for the communication system of these railroads; consequently the frequency range in which the UHF RFID system currently works should be modified. This paper compares the spectral range of the RFID system used nowadays, with the future scenario, for example, after the spectral modification range and it analyzes whether there will be a performance degradation in the reading rate of RFID systems currently established.**

Keywords: RFID Technology, ANATEL, TAV, ERTMS

I. Introduction

ANATEL, the National Agency of Telecommunications in Brazil, has the mission to promote the development of telecommunications in the country in order to give it a modern and efficient telecommunications infrastructure, capable of providing adequate services to society. Thus, ANATEL establishes the conditions of using radio equipment that uses frequency spectrum for transmitting a signal [1].

The transmission of an RFID system is regulated by Resolution 506 of 1 July 2008, section XII of ANATEL. As it will be described later there is a gap that cannot be used by the RFID system in the UHF range from 907.5 to 915 MHz. This frequency range is used for Personal Mobile Service (SMP), as described at Resolution number 454 of December 11, 2006 of ANATEL. This service has a primary character and is priority to the RFID system (secondary character). For example, the RFID system cannot be an interfering signal to the SMP signal.

Nowadays, there is a study being conducted by Spectrum Engineering of ANATEL, that intends to allocate a frequency band of 5.5 MHz at 902 MHz to be used in the communication system of the Brazilian high-speed train. This range coincides with one of the frequency range already used by the Brazilian RFID system today. It is considered a primary service just like the SMP, so the RFID system can no longer use this frequency range allocated to this service.

The high-speed train project in Brazil comprises the deployment, operation and maintenance of this high-speed train, called TAV Brazil. The project is 511 km long and it will connect the cities of Rio de Janeiro, São Paulo and Campinas and other cities along the way, at a maximum speed of 300 km/h [2]. Figure 1 shows the metropolitan areas and regions

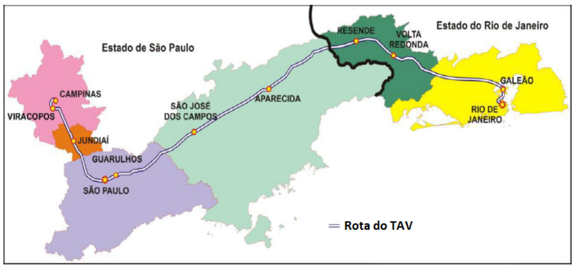

Fig. 1. Metropolitan areas and regions in which TAV will operate is called EF 222 [9].

in which TAV will operate. This stretch is called EF 222. The project is scheduled for full completion in 2020.

With the coordination of the Ministry of Transport and the National Land Transport Agency (ANTT) and the participation of representatives of the rail industry, a working group will define the standard to be adopted by the railroads. This pattern will become the standard of the Brazilian Association of Technical Standards (ABNT) and should be adopted throughout the Brazilian system. The standard for communication and signaling of future railroads will be based on the European model ERTMS, i.e. the European System of Rail Traffic Management, as the portal of National Land Transportation Agency (ANTT) [3].

This paper has the following objectives: to compare the spectral range of the RFID system of the current scenario with the future scenario, i.e., after the modification of the spectral range for the TAV project and to examine whether there is degradation of performance in the reading rate of RFID systems that are already implemented.

II. ERTMS - European Standard Used as a Basis for Communication and Signaling of TAV Brazil

The ERTMS [4] consists of the ETCS (European Train Control System) and the GSM-R (Global System for Mobile Communication Railway).

- European Train Control System (ETCS) is a unified European track-train transmission based train driving supervi-

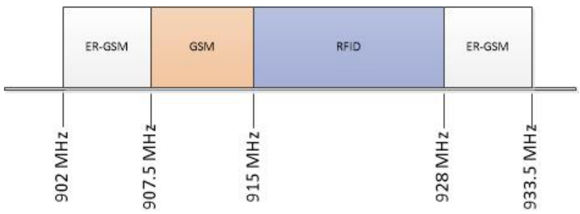

Fig. 2. Possible ranges of use for the communication system of the TAV Brazil.

sion system. It was elaborated in view of the rail transport liberalization to ensure rail transport competitiveness by using the same system in all European countries [5].

- GSM-R is an international wireless communication standard for railway communication and applications based on the GSM technology. It is developed as a platform for voice and data communications as well as for traffic control system for railway. GSM-R is accepted by many countries, including most European countries, China, and India. In Europe and China, GSM-R is successfully under implementation and replacing the old railway communication system [6]. GSM-R in Europe currently operates in the 2x4 MHz band above the 870 MHz and 915 MHz bands (i.e. 876-880 MHz and 921-925 MHz). An extension is currently being contemplated, known as ER-GSM, which could enhance the capacity and capability of the current service.

ER-GSM, Extended Railways GSM 900 system, is required to operate within the following frequency bands [7]:

- 873 MHz to 915 MHz: mobile transmits, base receives; and
- 918 MHz to 960 MHz: base transmits, mobile receives.

There is a possibility for Brazilian TAV system to use the communication pattern ER-GSM operating in 2X5.5 MHz, i.e. 902-907.5 MHz for the mobile to transmit, and for the base to receive and 928-933.5 MHz for the base to transmit, and for the mobile to receive. Figure 2 shows the possible ranges of use for the communication system of the TAV Brazil.

III. COMPARISON OF BRAZILIAN CURRENT SPECTRAL RANGE WITH THE PROPOSED RFID SYSTEM SCENARIO

A. Current scenario: ANATEL Resolution for the RFID system

In accordance with Resolution No. 506 of July 1^{st} 2008, the regulation on radio communication of radiation restricted equipment, the Radio Frequency Identification system is defined below.

System, comprising transceiver device, which sends and receives radio frequency signals when excited by interrogator transceiver equipment, which has the ability to perform the reading, writing or modification of the information contained in the device.

The Article 3^{rd} confirms that the restricted radiation equipment, i.e. also RFID readers, are exempt from registration or licensing for installation and operation. But they need to be approved. The approval is needed to verify that the equipment is operating according to the rules established by this resolution. The passive RFID tag (label) and semi-passive RFID tag don't need homologation, the active RFID tag needs to be homologated, because it contains active transmitter in its constitution.

In Section XII, Article 52, the Radio Frequency Identification Systems (RFID), can operate in the following bands: 119 - 135 kHz, 13.11 - 13.36 MHz, 13.41 - 14.01 MHz, 433.5 - 434.5 MHz, 860 - 869 MHz, 894 - 898.5 MHz, 902 - 907.5 MHz, 915 - 928 MHz, 2,400 - 2,483.5 MHz, 5,725 - 5,850 MHz.

The UHF RFID equipment operating in the bands 902 - 907.5 MHz and 915-928 MHz using Spread Spectrum technology, must meet the following requirements:

a-) maximum peak conducted output power of the intentional radiator shall not exceed 1 Watt for systems employing at least 35 hopping channels and 0.25 Watt for systems employing less than 35 hopping channels;

b-) if the bandwidth of the hopping channel is less than 20 dB at 250 kHz, the system shall use at least 35 hopping channels and the average occupancy of any channel shall not be greater than 0.4 seconds in a range of 20 seconds;

c-) if the bandwidth of the hopping channel to 20 dB is equal to or greater than 250 kHz, the system shall use at least 17 hopping channel frequency and the average occupancy of any radio frequency should not be more than 0.4 second in an interval of 10 seconds;

d-) the maximum bandwidth of the hopping channel to 20 dB must be limited to 500 kHz.

It is noteworthy that for RFID systems in accordance with paragraph (b) mentioned above, 10 hopping channels are in the frequency band of 902 - 907.5 MHz, and 25 hopping channels are in the frequency range of 915-928 MHz.

For RFID readers that use antennas to transmit, the resolution states: for devices that make use of transmitting antennas with directional gain greater than 6 dBi, the conducted output power from the intentional radiator shall be reduced below the stated values specified, i.e., 1 Watt (30 dBm), by the amount in dB that exceeds 6dBi of the directional gain.

B. Future scenario: after the allocation of bandwidth to the Brazilian TAV system

Using the range of 902 to 907.5 MHz by the TAV system, the spectral range designed for the RFID system will be only the range 915-928 MHz. The system uses 25 hopping channels. To comply with regulation 506 of the ANATEL, the maximum peak of conducted output power of the intentional radiator shall not exceed 0,25 Watt (24 dBm).

C. Comparison of the scenarios

If N is being the number of hopping channels, one channel will be used throughout the transmission in medium of $1/N$ transmission duration time. In the previous scenario, 35

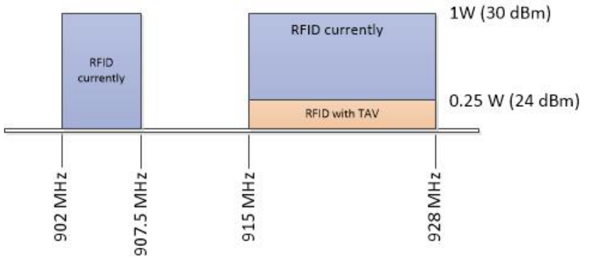

Fig. 3. Frequency bands currently used by the RFID system with the maximum permitted power and frequency range to be used by the RFID system after the implementation of the TAV system in Brazil.

hopping channels, the total average stays a single channel that is 0.0285 of the transmission time, the scenario after the introduction of the TAV in Brazil remained full time in a single channel is 0.04, i.e. 40.35% of greater permanence in a single hopping channel, this is reflected in a greater vulnerability as the interference with other devices that are sharing the spectrum simultaneously.

Therefore, to avoid this interference, the power must be reduced by 6 dB. Figure 3 illustrates the frequency bands currently used by the RFID system with the maximum permitted power and frequency range to be used by the RFID system after the implementation of the TAV system in Brazil.

This reduction in power causes a decrease of the reading range of a tag. The maximum range at which the reader can detect the tag [8] can be calculated as follows.

- Tag antenna collection area of 0.09 square meter, A_{RX} ;
- Interrogator's antenna effective collection area is 0.09 square meter, A_{SC} ;
- Interrogator using OOK encoding requires a signal-to-noise ratio of 12 dB to detect data (interrogator sensitivity);
- Typical date rate for systems is approximately 100 Kbps, giving the bandwidth of the signal at around 300 kHz;
- The noise power into a 50 ohm resistor at room temperature is -174 dBm/Hz, for 300 kHz, approximately 55dB;
- Noise floor at the signal frequency of 300kHz = 174 dBm + 55dB = -119 dBm;
- The minimum power that must be received by interrogator from the tag, P_{RX}: Noise floor + interrogator sensitivity

$$-119\ dBm + 12\ dB \ = \ -107\ dBm\ (2 \times 10^{-14}\ W)$$

Calculating the maximum range, r, using free space path loos from the interrogator to the tag and then back from the tag to the interrogator:

$$r = \sqrt[4]{\frac{P_{TX}}{P_{RX}} \frac{A_{RX} A_{SC}}{16\pi^2}}$$

- Scenario 1, $P_{TX} \ = \ 1\ W$:

$$r \ = \ 71\ meters$$

- Scenario 2, $P_{TX} \ = \ 0.25\ W$:

$$r \ = \ 50.32\ meters$$

Power reduction by 6 dB reduces approximately 30% in the maximum range at which a reader can detect the tag.

IV. PERFORMANCE ANALYSIS OF READING RATE OF THE CURRENT AND FUTURE SYSTEM RFID SCENARIOS

A. Test Setup

To obtain data free from external interference and accuracy in the measurements, all tests were conducted in a semi-anechoic chamber. The reader used has access to necessary modifications of frequency bands and power. The equipment manufacturer has provided the access so that the tests could be performed, but only inside the semi-anechoic chamber not breaking the current regulation by ANATEL.

Figure 4 shows the spectral frequency range used by the RFID system regulated by ANATEL currently generated by the reader Sirit Infinity 510; Figure 5 shows the spectral frequency range intended for RFID system after system implementation of the TAV Brazil.

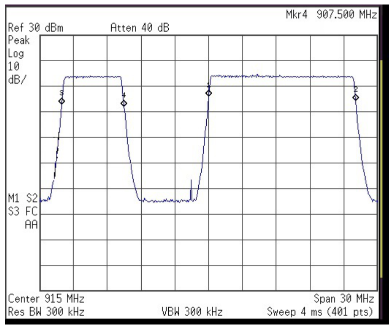

Fig. 4. Spectral frequency range used by the RFID system regulated by ANATEL currently

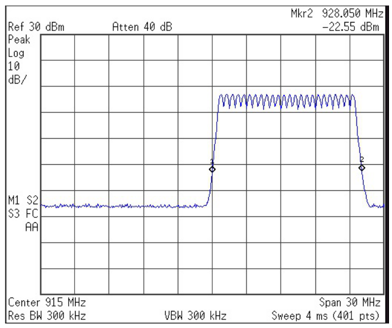

Fig. 5. Spectral frequency range intended for RFID system after system implementation of TAV Brazil.

Figure 6 shows the assembly of the set of tests. Two antennas with circular polarization were connected to the reader. These antennas are arranged on each side of the pallet facing each other. The distance between them is 85 cm. The antennas are 135 cm from the floor. A spectrum analyzer was used to verify the hopping channel used and their relative output power.

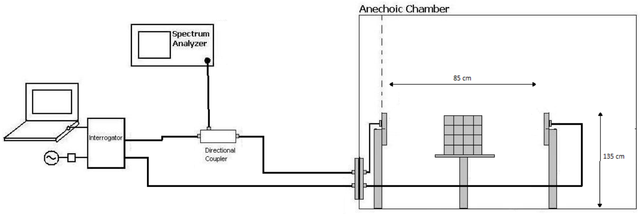

Fig. 6. Test setup.

One pallet was inserted in the semi-anechoic chamber containing boxes of test items. Each box had the following dimensions, 16.3 mm length, 10 mm height, 8 mm width. The item inside the box was tagged. Figure 7 shows (a) the item and (b) the respective pallet inside the semi-anechoic chamber. This test didn't have as objetive to compare different RFID tags, so all the items were tagged with same model of tags. All items that made up the pallet were tagged the same way.

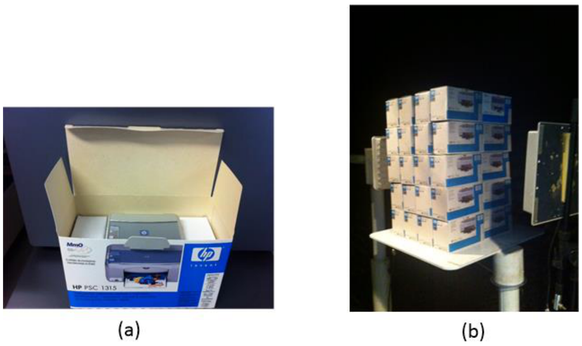

Fig. 7. (a) the item and (b) the respective pallet inside the semi-anechoic chamber.

B. Procedure

Steps were taken for the three types of scenarios:

- Current Brazilian Scenario, 35 hopping channels, operating band 902 - 907.5 MHz and 915-928 MHz and 1 W level of power, Full Band.
- Scenario after the implementation of TAV Brazil, 25 hopping channels, operating band 915-928 MHz, 0.25 W level of power, Band B (24 dBm).
- Ideal Scenario after TAV Brazil implementation, 25 hopping channels, operating band 915-928 MHz, 1W level of power, New Band B (30 dBm)

Steps:

1) The N items were placed inside the semi-anechoic chamber;
2) The transmitter of the reader was connected with the closed chamber.
3) It was recorded the following data after 1 minute of active transmission: tags reading, reading count, average rate, peak rate.
4) Other 8 items were placed in formation of pallet, and the procedure 2 was repeated.

The steps described above were carried out for N = 8, 16, 24, 32, 40, 48, 56, 64, 72, and 80 items arranged in formation of pallet

C. Results analysis of read rates performance

The graph in Figure 8 shows the total items in pallet versus the total items identified. Note that not all 48 tags on the Full Band were reached. This is due to the fact that there was no concern to have the best configuration for 100% reading rate, neither with the best tag for the item nor the best item positioning. Using Full Band as reference it was realized that the performance of the Band B 24 dBm level of power for small numbers of tags in the interrogation zone is the same as for Full Band. However, with the increase of tags in the scenario the reading rate is much lower, achieving a maximum of 34% difference between the reading recorded in Full Band and Band B (24 dBm).

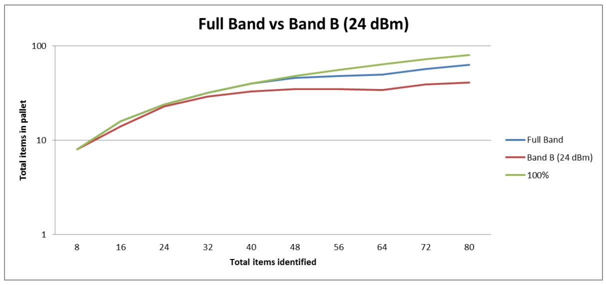

Fig. 8. Full Band vs Band B (24 dBm)

In order to avoid this reading rate degradation, it is proposed that even with a decrease in the number of hopping channels, the power level has to be 1 W (30 dBm), ideal scenario named as New Band B (30 dBm). The ideal scenario after the implementation of the TAV Brazil is the RFID system with 25 hopping channels, operating band 915-928 MHz, 1W level of power (30 dBm). It was realized that for this configuration the performance of the reading rate remained unchanged in comparison to the full system band, as shown in the graph of Figure 9.

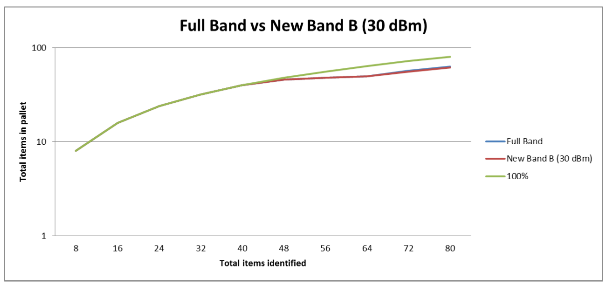

Fig. 9. Full Band vs New Band B (30 dBm)

Its possible to observe a comparison between the reading rates of both scenarios after the implementation of the TAV Brazil Band B (24 dBm) scenario and New Band B scenario.

The frequency range and, the number of hopping channels are the same for both scenarios, but the level of power in scenario Band B is 0.25 W and in scenario New Band B the transmitter output is 1W. It is observed that the setting New Band B has superior performance to scenario Band B (24 dBm), as graph of Figure 10. This is due to the fact that with the reduction in power the reading distance is smaller, and therefore the reading rate is also harmed.

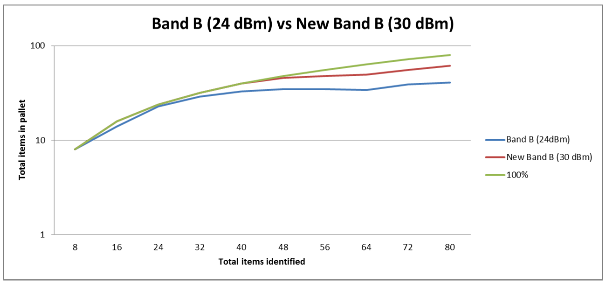

Fig. 10. Band B (24 dBm) vs New Band B (30 dBm)

V. Conclusion

In the graphic analysis and data acquired presented there was a significant drop in the reading rate with reduced level of power to 24 dBm, represented by the graph of Figure 8. This can directly impact all RFID applications already consolidated currently, and mainly in the equipment specification of the RFID system in Brazilian projects that are already underway, such as Brazil-ID and SINIAV, since they have defined technical specifications of equipment as well as projects in development considering the use of the entire frequency range as used today.

Additionally, in order to not be performance penalty, the level of power in the band B (915-928 MHz) has to continue with 30 dBm, since the reading distance and all the technical specifications of these projects are not significantly changed, as shown in the graph of Figure 10, and can in this way continue with the implementation that can be done the same way without any major impacts. On the other hand, with the reduced number of hopping channels, the occupation time (or repetition) of a specific hopping channel will occur more frequently, resulting in an increased likelihood of interference with other devices that are using the same medium. One way to reduce this impact would be a reduction in peak power system transmission schemes that use a hopping low-channel. But for this to happen, it is necessary a review of the current ANATEL 506 regulations, changing the maximum output power for equipment that operates with hopping channels.

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