Channel Sounder and Broadband Measurements for Railway Systems

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***Abstract*—When a radio signal is transmitted in a real propagation environment with various objects or buildings, the signal may be distorted or impaired because of the diffraction, scattering or absorbing. This situation is specially important on a complex railway environment. Therefore, the channel modeling of propagation on a railway environment becomes a hot research field. As the demands for broadband wireless data transmission raising, it is essential to characterize the wireless channel in modern railway system. In this paper, we designed and manufactured a broadband channel sounder system with high power (42dBm) and covering from 0.5 GHz to 6 GHz in different bands. Otherwise, the receiver provides a sensitivity of -100 dBm with 100 MHz bandwidth and an available gain up to 65 dB. Through the test trials we did in the metro station and tunnels, can prove this channel sounder is able to measure the behave of radio wave propagation that will be very useful for channel modeling in complex railway environments.**

***Index Terms*—modeling, propagation, railway, channel sounder, tunnel**

I. Introduction

In recent years, wireless communication has explosively developed in many areas. In the railway communication systems, Global System for Mobile Communications-Railway (GSM-R) is still a widespread standard for most of railway communication systems, However, it can only support narrowband applications [1]. For future railway communication system, the drawback of GSM-R that has the low data capacity cannot meet the requirements like real time video or other high capacity data transmissions [2]. Thus, the broadband radio communication system for railway is urgent and necessary, which can support strong quality of service demanding applications and added value services [3].

The channel characteristics of a broadband communication system directly determines the transmission performance of the system. An accurate radio propagation measurement is the basis for high-performance channel modeling [4]. The railway wireless communication system has its own challenge: fast-moving train and rapid changes in terrain during the driving, lead to a complex and diverse propagation environment. However, the channel sounders in the past only work on a single band. This paper presents a flexible multi-band, extensible, and versatile architecture for a hardware channel sounder, which is designed to measure the performance of broadband signals in railway environments and has ultra wide band capabilities. For verifying the validity and efficiency of this system, a series of broadband measurements are conducted in a real subway environment at both 2450 MHz and 1000 MHz.

This work is supported by the Spanish Ministry of Economy and Competitiveness within the project IPT-2011-1034-37000 (TECRAIL).

II. Broadband channel sounder

The measurement of propagation characteristics is a complex and very important step in planning a mobile radio system. Accurate equipments and rational approaches are required to determine parameters of a wireless system that will provide efficient and reliable coverage in different scenes at different frequencies. With huge technological effort, many research institutes have done a lot of research[5]. A channel sounder is a system that measures how wireless signals behave in the specific environment. The channel sounder proposed in this paper is a suit of radio frequency (RF) transmitter and receiver, which can operates as the interface of baseband and synchronization system with the propagation channel, and it is composed by a complete RF transmitter front-end and dual conversion receiver. It is worth to mention that this channel sounder system covers all LTE and LTE-Advanced frequency bands. When it combines with a baseband subsystem, it can be a hardware demonstrator to measure LTE performance in railway environment.

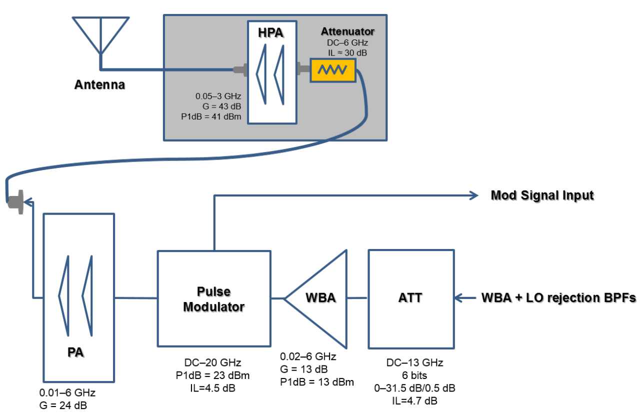

Fig. 1: Transmitter RF front-end.

As Fig. 1 shows, There are two different power amplifiers provides enough gain to amplify the output signal to be

Transmitter		
Frequency range	500-6010 (4 bands)	MHz
Output power	42	dBm
IF bandwidth	1/10/30/100	MHz
Modulation	Pulse/external	10 ns/ LTE
Receiver		
Frequency range	400-7000 (4bands)	MHz
IF dual conversion	860/160	MHz
Noise figure	3	dB
IF bandwidth	5/10/20/100	MHz
Demodulation	Logarithmic detector	/LTE
Dynamic range	90	dB

TABLE I: Parameters setting up for the channel sounder.

transmitted with the desired level. In detail, the maximum output power of medium power amplifier (PA) is 29 dBm, and for the higher power amplifier (HPA), the maximum level is 42 dBm. Simultaneously, the transmitter RF front-end can operate in continuous wave (CW) or pulsed mode (PM) by RF pulse modulating module, which is going to be used to measure the parameters associated with the impulse response of the wireless channel by channel sounding techniques. Therefore, this unit comprises mainly a SPST Pin diode switch that can be used for RF pulse modulating, and choosing the power amplifier level. Ultimately, the amplified signal is transmitted to the wireless channel under test through the antenna.

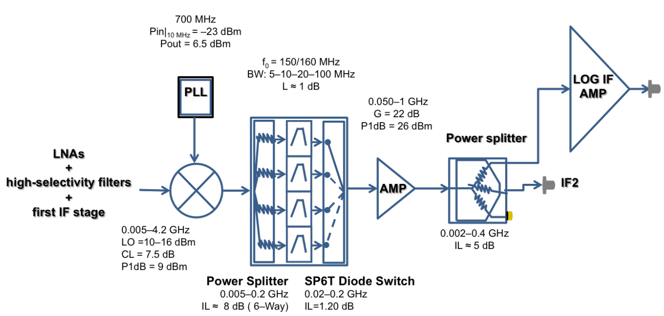

Fig. 2: Receiver RF front-end.

Correspondingly, the RF receiver front-end is in charge of converting the high frequency of received signal to an intermediate frequency (IF). It is designed to a dual conversion structure after an input filter bank, which with four bandwidth selections to provide for different operation modes of LTE system. Hence the first IF (850/860 MHz) stage for connecting with the baseband unit for LTE signal processing.

For the channel sounding operations, the receiver RF front-end has a second down-converting to IF2 equal to 150/160 MHz as Fig. 2 illustrates. In this stage, it is composed by a second mixer, an amplifier and a filter bank for bandwidth selection, and a suitable logarithmic detector placed at the end. The logarithmic is used to demodulate the received pulse and a RF power meter are included to provide measurements in the channel sounder operation mode. The real channel sounder hardware are manufactured as Fig. 3 shows. After the compact hardware design and rigorous testing. The technical specifications of the whole channel sounder system list in Table 1.

Fig. 3: Channel sounder transmitter and receiver.

Fig. 4: Testing in the metro station.

III. Test trials on railway environment

Wave propagations in railway environment has some important differences compared to the other cases, due to the special characteristics of the scenarios like tunnels, viaducts and cuts [6]. In order to characterize the radio channel in typical subway environment, two groups of broadband test carry out in a subway station (see Fig. 4) named “Ciudad de los Angeles” (Line 3 of Metro de Madrid) [7]. For considering the effects from the train and subway station, the first group is designed as Fig. 5 illustrated, both transmitter and receiver devices are located on the station platform. while the second group is set up like Fig. 6 shows. In this case, the antenna of the transmitter is installed on a tripod and placed on the station platform, while the receiving antenna is adsorbed on the windshield of the train’s tail. It is designed for detecting the effects from the tunnel, the measurements are operated inside the subway tunnel that connect the aforementioned station. During these two groups testing, the channel sounder works on 2450 MHz and 1000 MHz, respectively. Both transmitter and receiver are synchronized by using the baseband pulse (47 ns pulse width) generated on the transmitter side.

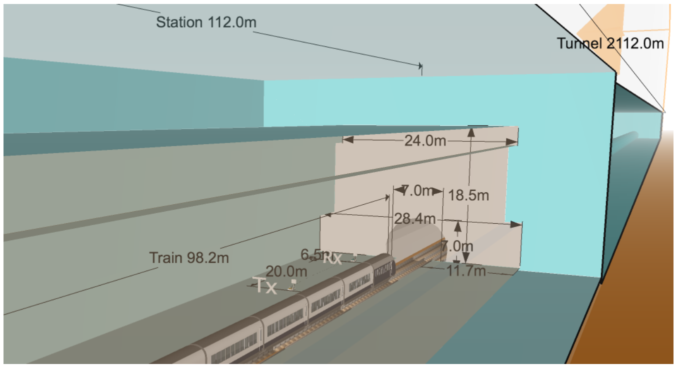

Fig. 5: 3D scenario for the first group testing.

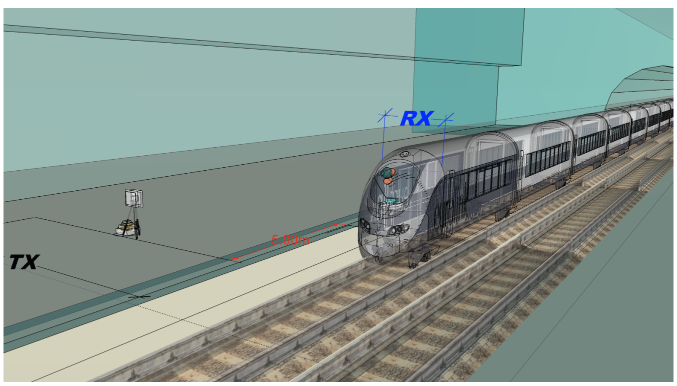

Fig. 6: 3D scenario for the second group testing.

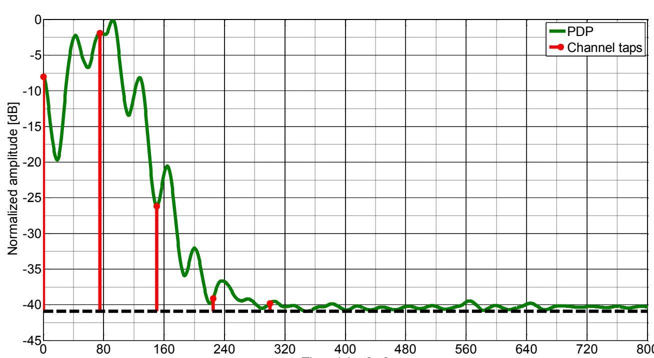

Fig. 7: Measurement result when the train is in the middle of the metro station.

On the receiver side, the received signal is demodulated by the logarithmic amplifier (LOG IF AMP). Therefore, the measurement results are a set of power delay profiles (PDPs) which give the amplitude of the received signal in every instance through a multi-path channel as a function of time delay. Base on the PDPs, certain channel parameters can be extracted. For instance, the delay spread is useful to determine the number of channel taps, which is one of the key parameters needed for signal propagation models [8]. The Fig. 7 demonstrated the measurement result obtained from the scenario of Fig. 5 that the train is located in the middle of the metro station. It can be figured out since the train is very near the channel sounder equipments, larger contribution can be found in the time delay axis around 80 ns, which corresponds to around 24 m path length. This could be the first order reflection from the wall of the station. Base on the measurement result like Fig. 8 in the second group testing at 2450 MHz, we can analyze from two aspects: (1) From the amplitude, when the distance is short, the amplitude fluctuates greatly. That implies in the tunnel, there are lots of multi-modes under the near-field zone condition. While the magnitude changes slowly with the increasing distance since the far-field conditions. (2) On the other hand, the root mean square delay spread (RMS-DS) in tunnels is smaller than in the metro station at the same frequency, due to the narrow space inside the tunnel. Meanwhile, the longer distance results in greater attenuation of the reflected ray.

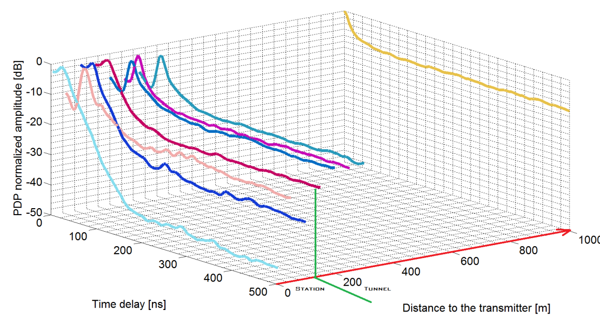

Fig. 8: 3D plot of the 2nd group testing result at 2450 MHz.

IV. Conclusion

A flexible and versatile architecture channel sounder are presented in this paper. It can be used for channel sounding independently and extended used to measure the LTE performance in railway environments. We describe in detail the hardware combinations and configurations. In the corresponding broadband measurement, we design two groups test trials to consider the effects from different objects by the data captured from oscilloscope. From the discussion on the measurement, the magnitude of the channel impulse response contains many effective information about the propagation channel and behave of the radio signal. The next step will focus on the multi-antenna channel sounder, where typically multiple transmitting and receiving antennas in conjunction with signal processing or data reduction techniques are used. Otherwise, we can compare the measurement results with the ray tracing simulation in the 3D scenarios created in this project.

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