Measurement 110 (2017) 53–59

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Self-interference suppression improvement by employing circular polarized antennas

M. Portela Táboas, M. Vera-Isasa, M. García Sánchez *

Department of Teoría do Sinal e Comunicacións, Universidade de Vigo, Vigo, Spain

ARTICLE INFO

Article history:
Received 25 March 2017
Received in revised form 12 June 2017
Accepted 15 June 2017
Available online 16 June 2017

Keywords:
Full-duplex
Self-interference
Passive suppression
Analogue cancellation
Directional antennas
Circular polarization

ABSTRACT

This paper presents a novel method for suppressing the self-interference due to multipath in WiFi nodes of full-duplex systems based on employing two circular polarized antennas. Three different techniques have been used in order to suppress the interference generated by the direct wave: antenna separation, antenna pattern and analogue cancellation circuit comprised of a balun, a phase shifter and a variable attenuator. As a result, an initial isolation of 90 dB was achieved inside an anechoic chamber. In order to beat the multipath interference circular polarization was employed. With the aim of analyzing the robustness of the circular polarization in comparison with the linear one, the self-interference between transmitter and receiver was measured in nine different environments. The measured level of self-interference was also compared with the results achieved inside the anechoic chamber. In this way, the degradation of the self-interference suppression due to multipath was evaluated. Results show better isolation when employing circularly polarized antennas in seven of nine environments. In addition, with the circular polarization self-interference suppression higher than 70 dB was achieved independently of the environment.

1. Introduction

The self-interference (SI) between two antennas (transmitter and receiver) located in the same node of a WiFi system, working simultaneously and at the same frequency is one of the challenges in implementing a full duplex wireless device. SI is mainly defined by two components: the self-interference due to the direct path coupling between the antennas of the node and the interference owing to multipath produced by the signals reflected, diffracted and scattered in the environment where the system is deployed. In the literature, different solutions can be found to address the SI cancellation problem, which can be divided into three different categories: propagation, analogue and digital self-interference suppression [1]. The first one is based on passive techniques such as antenna directivity [2], antenna separation [3], antenna cancellation [4], passive RF circuits [5], or a combination of some of these methods [6], including the use of cross-polarized antennas. The second one implies to generate an attenuated and phase-inverted copy of the transmitted signal which is added to the received one as in [7,8]. Both techniques have been widely used to mitigate the interference produced by the direct wave. Each technique presents advantages and disadvantages but, in general, they reach to solve the intended problem. Once the direct wave interference problem has been mitigated the multipath becomes the main interference issue. Many authors agree in applying digital self-interference cancellation in order to beat the multipath interference [7,8]. Most of them are focused on estimating the radio channel by employing a pilot carrier that transmits a known signal. In such a way, it is possible to distinguish the part of the received signal which is due to the self-interference since we know what the channel response is. This technique implies to waste a part of communication resources on doing the estimation and subsequent correction of the signal.

In this context, the goal of this work is based on showing how useful circular polarization is as a method for decreasing the self-interference due to multipath. One of the most important characteristics of the circular polarization is that, when the transmitted signal is reflected over a plain surface (wall), the sense of rotation is reversed. Thus, this counter-clock-polarized signal will be filtered for a receiver antenna working with the same polarization as the transmitter one. In the paragraph below, we will explain the steps followed to assess the proposed solution.

In Section 2, a description of the measurement system is done. Firstly we describe the passive and analogue techniques which were used to cancel the SI generated by the direct wave. Then,

* Corresponding author.
E-mail address: manuel.garciasanchez@uvigo.es (M. García Sánchez).

http://dx.doi.org/10.1016/j.measurement.2017.06.022
0263-2241/

we explain the characteristics of the antenna employed. In Section 3, the environments where the measurements were carried out are presented and the process followed to do them is explained. The results obtained from the measurement campaign are analyzed in Section 4. Finally, in Section 5 we expose the main conclusions that can be extracted from the analysis done.

2. Measurement system

In order to compare the robustness to multipath of the full duplex systems when operating with linear and circular polarization two requirements should be addressed. First of all, the self-interference generated by the line-of-sight path has to be suppressed. In second place, an antenna capable of working with both polarizations is necessary.

In this work, three different techniques have been used in order to eliminate the interference generated by the direct wave. The first one lies in applying 15 cm of separation between antennas. This technique provides an initial isolation of 20 dB. The second technique involves using directional antennas instead of the traditional omnidirectional. In addition, due to its simplicity and good results achieved, we decided to employ the analogue cancellation circuit presented in [7]. It is comprised of a balun, a variable phase shifter and a variable attenuator.

Fig. 1 shows the complete block diagram of the WiFi node. We have employed a PNA Network Analyzer N5222A of Agilent Technologies in order to measure the self-interference (S21 parameter) generated in the node.

A circular patch antenna was designed for the measurements by using the software CST Studio Suite. Fig. 2 shows a front view of the antenna design. It consists of a circular patch over a ground plane that is at the back face of the printed circuit board. The circular path is fed in two different points by using a 90° hybrid coupler. The antenna will work with circular polarization when just one of the two ports is excited. However, when both ports of the hybrid coupler are fed with the same excitation simultaneously, the antenna will transmit a linearly polarized signal. Measured copolar and crosspolar radiation patterns in both working modes, circular and linear, are shown in Figs. 3 and 4 respectively. In addition, the antenna fulfils the following requirements: it works at WiFi ISM band, i.e. it is matched from 2.4 to 2.48 GHz (Fig. 5). It has a directional beam pattern with high beam width (100° approximately) and a measured gain, at 2.4 GHz, of 5 dBi for linear polarization, and 4 dBi for circular polarization. This kind of antennas provides additional self-interference suppression [2] whereas guarantee good quality signal between WiFi nodes.

The final setup is shown in Fig. 6. As a result of applying the mentioned passive and analogue cancellation techniques, an initial isolation of 90 dB was achieved inside an anechoic chamber.

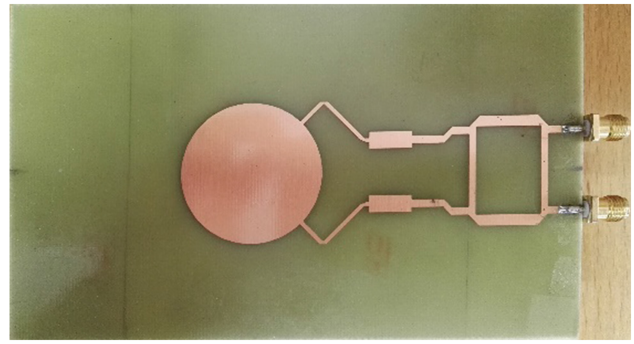

Fig. 2. Front view of the antenna used for the experiments.

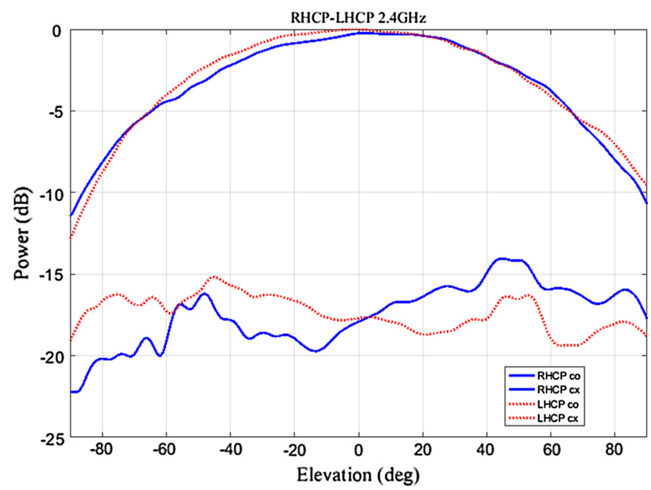

Fig. 3. Measured circular polarized co and crosspolar radiation patterns (left-hand, LHCP, and right-hand, RHCP) at 2.4 GHz.

3. Measurement campaign

The measurement campaign was performed in nine different environments as shown in the sketch of Fig. 7 and the pictures in Fig. 8.

The walls in the first environment (named 1 in plots and table of results) are composed of absorber material, an insulating carpet covers the floor, and the ceiling (as in all cases) is made of plasterboards. Due to this fact, the main characteristic will be the absence of reflections.

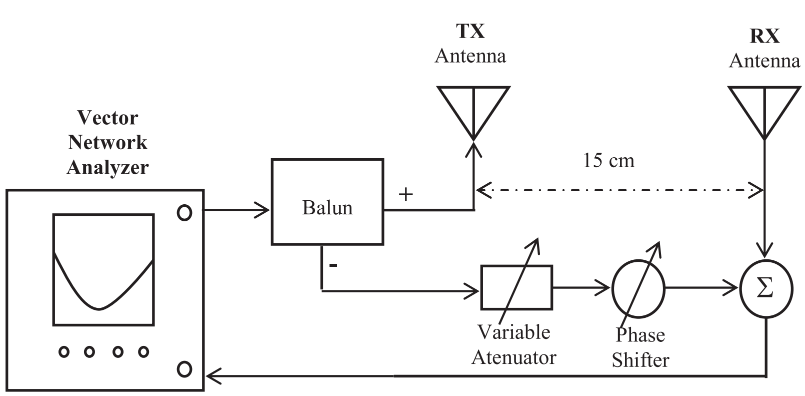

Fig. 1. Block diagram of the full duplex system node.