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Towards Identification for Harmonic Transponders

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Abstract

In this paper we present a technique allowing to identify harmonic transponders. The approach relies on the evolution of the backscattered power at a given harmonic frequency as a function of the fundamental frequency. Thus to identify an harmonic transponder, the associated reader sweeps a continuous wave in the considered bandwidth. Experiments are done based on a vector network analyzer, the method is able to identify two different RECCO reflectors. A study on the read range is also included. These harmonic transponders allow to drastically increase the read range compared to the one associated to linear time-invariant systems such as chipless tags.

1 Introduction

Non-Linear transponders offer interesting properties compared to linear transponders used in the chipless technology [1]. The basic principle allows the transponder to receive an incident power at a frequency f_0 but to backscatter (a part) of the power at a frequency nf_0. The associated reader should thus be composed of a transmitter at f_0 and a receiver at $2f_0$ (or $3f_0$) and the architecture is similar to well-known harmonic radars [2]. Fig. 1 presents the basic concept of the harmonic reading system.

Note that harmonic transponders are composed by at least one non-linear element which is usually a Schottky diode due to its low threshold voltage value. Moreover these transponders can be fully passive *i.e.*, they do not require the presence of a battery which significantly reduces their cost and limits the maintenance.

The beauty of these transponders is that they offer a natural robustness to radar clutter interference. Since all objects present inside the environment are linear time-invariant systems, their responses to a continuous wave (CW) at f_0 are only located at f_0. Thus, this technique allows to easily separate the transponder response (which is located at $2f_0$) from the response of any object present inside the environment (only located at f_0). This property holds even if the backscattered power at nf_0 is significantly lower than the one reflected at f_0. Thus, harmonic transponders provide a higher read range compared to linear time-invariant transponders used for example in the chipless technology.

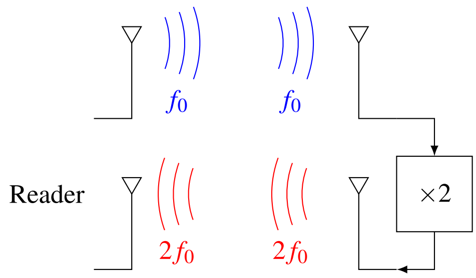

Figure 1. Principle of the harmonic reading system.

Harmonic transponders are not new in the literature and many examples are available. In [3], authors use harmonic transponders to detect presence of insects. In [4], authors propose an harmonic transponder composed of a single port. Finally, in [5, 6], authors exploit the non-linearity of classical RFID tags to realize harmonic transponders at $3f_0$. Commercial applications are also available, the RECCO system is based on harmonic transponders to detect victims in harsh environment at distances higher than 80 m in free-space and 20 m through packed snow. However, in all these papers, note that the harmonic signal is used only to detect the presence of the transponder but does not allow to identify it (*i.e.*, to make a difference between two tags for example).

In this paper, we address the problem of distinguishing and identifying an harmonic transponders based on its backscattered signal. The proposed technique is applied on two harmonic transponders (RECCO reflectors) and the proposed solution allows to identify each transponder at a given distance.

2 Results

2.1 Identification

Classical interrogation scheme used to detect an harmonic tag can not be employed to realize identification since the backscattered signal at $2f_0$ (or $3f_0$) does not carry any useful information to identify the tag (amplitude and phase of the reflected signal cannot be used reliably since both parameter depends on the distance and/or the received power).

However, note that the variation of the backscattered power at $2f_0$ (or $3f_0$) as a function of the fundamental frequency

Figure 2. Measurement bench used in the study. Inset: Harmonic transponders (REECO reflectors).

can be used to encode an information allowing to identify the tag. In this case the reading of the harmonic tag can be done by sweeping the fundamental frequency of the transmitter in a given bandwidth and by collecting the received power in the harmonic bandwidth. Note that, at each given instant, a single frequency f_0 is generated and a single frequency nf_0 is received. The idea of this paper is to use this signature, $A_{tag}(nf_0)$, which depends only on the harmonic transponder, to be able to identify the tag.

As in [7], the proposed approach can easily be implemented based on a Vector Network Analyzer (VNA) with frequency offset option. This method allows to uncouple the local oscillator used in the source and the local oscillator used in the receiver. For measuring the response of an harmonic tag, the receiver frequency is set to n times the frequency used by the source. Note that, in this case, the resulting plot does not correspond anymore to a S-parameter but to the signal directly seen by the receiver (without normalization by the reference).

For the study, we consider two harmonic transponders based on RECCO reflectors. These transponders are usually integrated into clothes and are also available on Ebay or Amazon for few dollars. Note that these transponders are classical harmonic transponders and have not been optimized to be identified. Measurement bench used to characterize the transponders is presented in Fig. 2 and is composed of a PNA 5222A connected to a UWB antenna A.H. Systems, inc. SAS-571. Harmonic transponders are presented in the inset of Fig. 2 and are placed (one at a time) at a distance of 50 cm from the antenna. Transmitted power has been set to 10 dBm and the sweep for the fundamental frequency is between 700 MHz and 1.2 GHz.

Supposing a linear environment impinged by a CW at f_0, the power at nf_0 is strictly equal to 0. However, in real measurement, a significant power at nf_0 is present on the receiver when the transmitter operates at f_0 due non-

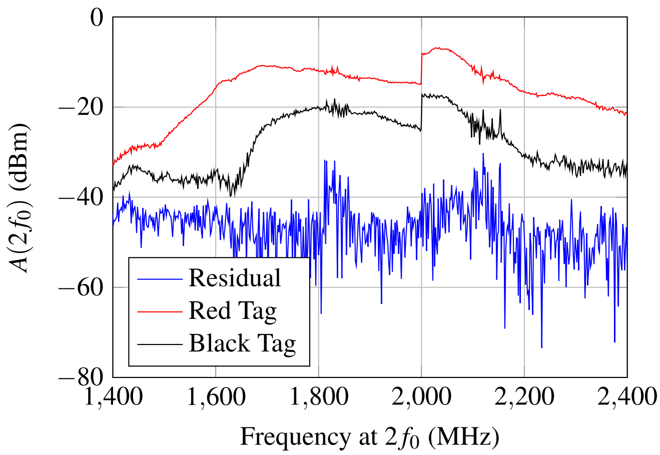

Figure 3. Received power at the second harmonic.

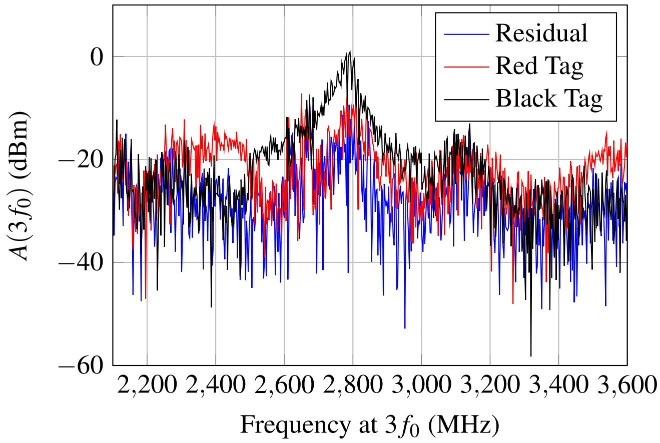

Figure 4. Received power at the third harmonic.

linearities present inside the instrument receiver. Fortunately, this power (which depends on f_0) can be easily characterized and compensated. Thus in order to isolate the tag response, a first measurement is done without the harmonic tag. The response of the tag is finally obtained by:

$$A_{tag}(nf_0) = A_{raw+tag}(nf_0) - A_{raw}(nf_0) \qquad (1)$$

Even if (1) looks like to the empty environment procedure used in chipless [1], note that $A_{raw}(nf_0)$ does actually not depend on the environment (which is linear and only reflects power at f_0) but only on the instrument imperfections. Thus, environment can be changed without affecting $A_{raw}(nf_0)$ which provides a natural robustness to the approach compared to the classical methods used in chipless.

Signals backscattered by the harmonic tags at the second harmonic are presented in Fig. 3. These responses can be compared to the residual response when no harmonic tag is present. First, note that the detection can easily be done by remarking that the received power is higher when a transponder is placed in front of the antenna compared to the case where no transponder is present. Second, the two transponders can easily be identified from the difference of their signature. For example, the red tag is characterized

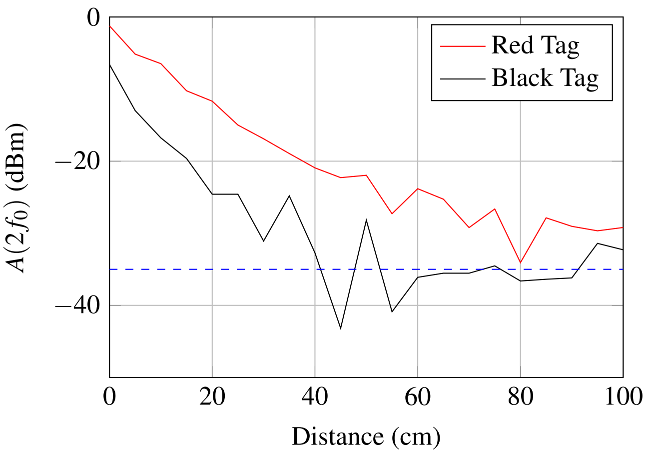

Figure 5. Read range associated to the presented harmonic transponders at 915 MHz.

by an higher harmonic power and an increased bandwidth (around 1.6 GHz) compared to the black tag. Note however that this signature still depends on the distance (and the transmitted power), so tags can be identified only if they are located at the same distance.

Fig. 4 presents the same results at the third harmonic. Note that even if the received power at this harmonic higher than the one obtained at the second harmonic, the difference between the residual response and the tag response is lower. Thus, even if the harmonic tags can be detected at $3f_0$, identification cannot be realized easily.

2.2 Read Range

A study of the read range has been realized by measuring the received power at the second harmonic as a function of the distance for $f_0 = 915$ MHz. Note that the transmitted power of the VNA is fixed at 10 dBm. Results are presented in Fig. 5. Note that the received power at the receiver does not follow the radar equation since the conversion loss between f_0 and $2f_0$ is not constant and function of the power received by the transponder [4]. The maximum read range associated to the transponder can be determined by estimating when the received power is equal to the residual power of the instrument. This power can be extracted form the value of the residual measurement at $f_0 = 1830$ MHz in Fig. 3 and is equal to -35 dBm. Dashed line have been reported in Fig. 5 to easily estimate the read range of each tags which corresponds to 60 cm and is higher than 1 m for the black and red tag respectively. Note finally that the output power of the VNA was only 10 dBm which is much lower than the maximum equivalent isotropic radiated power of 36 dBm allowed in the ISM band.

3 Conclusion

In this paper, a method allowing to identify different harmonic transponders is presented. The proof of concept is based on a vector network analyzer with frequency offset option and is able to identify different RECCO reflectors (designed for detection only). The proposed systems can to detect the presence of a tag at a distance higher than one meter with a power of 10 mW which is impossible to do with classical linear time-invariant systems used in the chipless technology.

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