# Harmonic Radar Transponder for Microsensing Systems

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***Abstract*—A harmonic transponder design suitable for microsensing systems is presented. The transponder is a passive device and operates at millimeter-wave frequencies to reduce its size and weight. The receive band is 38-38.5GHz and the transmit band is 76-77GHz. The transponder is formed from two planar microstrip patch antennas and a frequency multiplier circuit, and its minute size and weight make it an attractive option for tracking small objects or animals.**

***Keywords—Harmonic radar; microstrip patch antenna; harmonic transponder; microsensing system***

## I. INTRODUCTION

Harmonic radar has proven to be a popular method for tracking small biological targets such as insects [1], and has important applications to other areas as well. Traditional radar techniques are less effective for very small targets, because the reflected signals from the environment such as terrain and vegetation, also known as "clutter", is typically greater than the reflected signal of the target. This difficulty may be overcome through the use of harmonic radar, where the item to be tracked carries a small, lightweight, low-cost transponder that produces a second harmonic in response to the transmitted radar signal. The harmonic radar receiver is tuned to the second harmonic, which eliminates the clutter from the fundamental signal. Harmonic radar has been used to successfully track entomological targets such as bees [1] and beetles [2] using a fundamental frequency of 9.4GHz and the second harmonic of 18.8GHz. In this paper, a preliminary design for a harmonic radar transponder that operates at millimeter-wave frequencies is presented.

## II. HARMONIC RADAR AND TRANSPONDER

A schematic diagram of the harmonic radar system and a harmonic transponder is presented in Fig. 1. Use of a Frequency Modulated Continuous Wave (FMCW) radar system [3] will allow both range and velocity of the transponder to be estimated. The configuration of the harmonic transponder circuit is shown in Fig. 2. It consists of two inset-fed microstrip patch antennas [4] that are connected to each other using a x2 multiplier circuit. The larger patch operates at the fundamental frequency of 38.25GHz and the smaller patch operates at the harmonic frequency of 76.5GHz. These particular bands have been chosen to enable use (after some modification) of a commercially available automotive radar system, that operates from 76-77GHz, as the radar receiver.

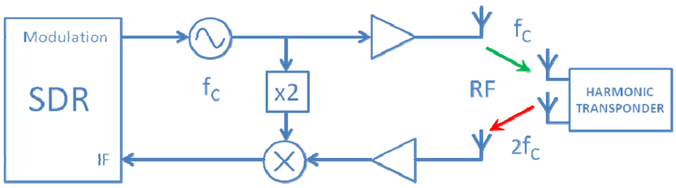


Fig. 1. Block diagram of harmonic radar system.

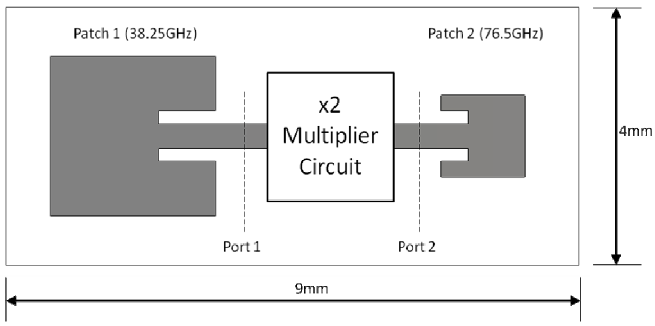


Fig. 2. Configuration of passive harmonic transponder circuit.

## III. ANTENNA DESIGN

The inset-fed patch antennas, shown in Fig. 1, have been designed using CST Microwave Studio [5]. Both the antennas and multiplier circuit are printed on a low-loss 0.127mm thick RT/Duroid 5880 substrate ($\varepsilon_r$ = 2.2, tan $\delta$ = 0.0009). Varying the length of the patch antenna controls its resonant frequency, while changing the inset length varies the input impedance, which in this case is matched to a 50 Ohm microstrip transmission line. The simulated reflection coefficient for port 1 of the transponder is displayed in Fig. 3, and shows that the return loss is greater than 10dB from 38.0 to 38.5GHz, the target bandwidth. Simulated performance of port 2 ($S_{22}$) is presented in Fig. 4 and confirms its return loss is better than 15dB from 76-77GHz. The simulated gain of patch antenna 1 is 6.9dBi at 38.25GHz, and the gain of patch antenna 2 is 8.8dBi at 76.5GHz.

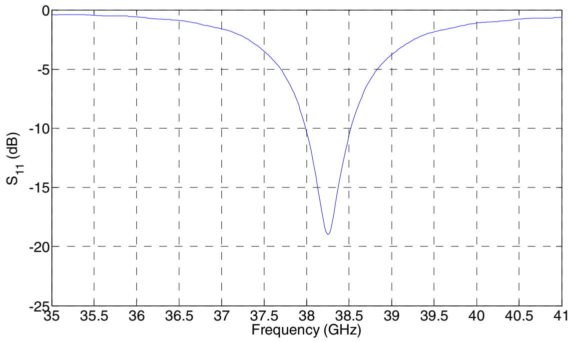


Fig. 3. Simulated reflection coefficient ($S_{11}$) for port 1 of the transponder.

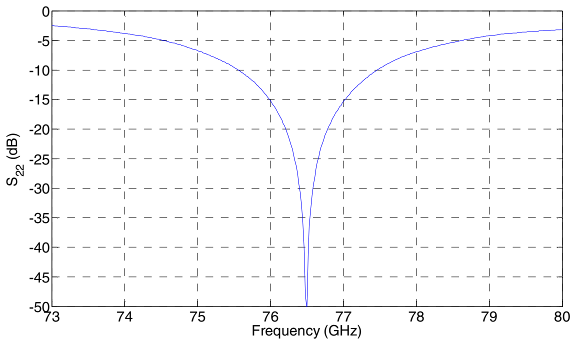


Fig. 4. Simulated reflection coefficient ($S_{22}$) for port 2 of the transponder.

## IV. Multiplier Design

The multiplier circuit used in the transponder is based on a typical design where the filters are realized using a short circuit λ/4 stub at the input and an open circuit λ/4 stub at the output [6]. In this implementation the Skyworks DMK2790 GaAs Schottky diode is used as the nonlinear element of the multiplier. A circuit diagram of the x2 multiplier is depicted in Fig. 5, and it has been analysed using Ansys Designer 2014 [7]. The computed harmonic conversion efficiency of the x2 multiplier is presented in Fig. 6 for an input frequency of 38.25GHz and harmonic frequency of 76.5GHz. This figure shows the efficiency has a linear dependence on the input power, for input powers from -30 to 0dBm.

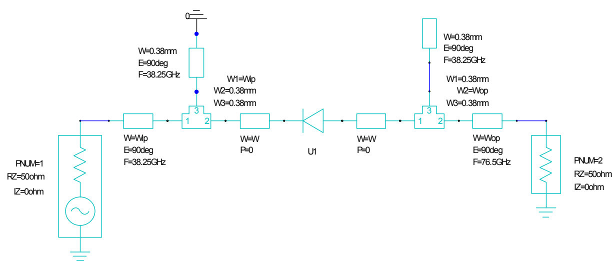

Fig. 5. Circuit diagram of the x2 multiplier circuit

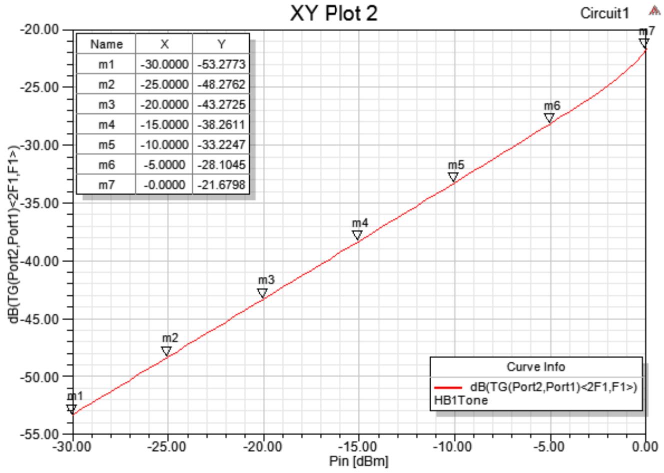


Fig. 6. Conversion efficiency of the x2 multiplier circuit.

## V. Conclusion

Preliminary design results for a harmonic transponder suitable for a microsensing system have been presented. Electromagnetic analysis results confirm the antennas operate efficiently in the bands 38-38.5GHz and 76-77GHz. A passive x2 frequency multiplier has also been shown to work successfully, with the conversion efficiency a function of the input power. While the overall size of the proof-of-concept transponder is 4x9mm, it is expected that this can be reduced significantly in the future. More details on the transponder, including measured data, will be presented at the conference.

## References

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