Compact Dual-Band Parasitic Dipole Antenna for Harmonic Transponders

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***Abstract*—A compact dual-band antenna employing parasitically coupled dipoles in an open-sleeve dipole configuration for use in harmonic transponders at 2.475 / 4.95 GHz is proposed. Its theoretical performance characteristics between 2 and 6 GHz are presented as determined through full wave simulation in CST Microwave Studio. The antenna is shown to have high radiation efficiency at both the fundamental frequency and the second harmonic while allowing independent control of the two resonances.**

***Index Terms*—Dipole antennas; dual band; harmonic transponders**

I. INTRODUCTION

Harmonic transponders for tracking animals, particularly insects, often use simple, non-optimised dipole or monopole wire antennas with accordingly limited performance [1], [2]. Newer developments employ two separate patch antennas optimised for receiving at the fundamental frequency and transmitting at the harmonic [3], [4]. In this application area, it is desirable to decrease antenna size and weight in order to minimise the disturbance to the animal being tracked. While there are developments towards designing patch antennas for dual band use [5], this work proposes a single optimised dual-band antenna design consisting of a main dipole with two additional parasitically coupled dipole elements which are tuned to the second harmonic. Similar open-sleeve dipole antenna designs have been used to enhance the bandwidth of a dipole antenna using two just slightly shorter parasitic dipoles [6]. Also aimed at dual-band operation with a frequency ratio of two, Chen *et al.* developed a dual-band slotted dipole antenna with four additional dipole elements placed at the outer ends of the primary dipole [7], mainly with the intention to obtain similar radiation patterns for the fundamental and the harmonic and aimed at uses in mobile telecommunications like GSM 900/1800. This paper presents the structure of the proposed antenna along with its performance characteristics obtained through simulation.

II. ANTENNA STRUCTURE

This antenna is intended to be a low frequency prototype operating at 2.475/4.95 GHz within the ISM bands, selected for availability of prototyping and measuring equipment as well as for spectrum licensing reasons. The design objectives were to simultaneously minimise $|S_{11}|$ at both, the fundamental $f_0 = 2.475\,\text{GHz}$ and the harmonic $f_1 = 4.95\,\text{GHz}$, while being matched to $Z = 50\Omega$ at its central balanced feeding port. Fig. 1 shows the structure and dimensions of the proposed antenna. It consists of a main dipole which is shortened by adding tee sections at its ends accompanied by two smaller dipoles tuned to the harmonic frequency placed closely alongside it to achieve strong parasitic coupling. It is designed to use a standard FR-4 substrate, 0.8 mm thick (dielectric constant $\epsilon_r = 4.3$, loss tangent $\tan\delta = 0.02$).

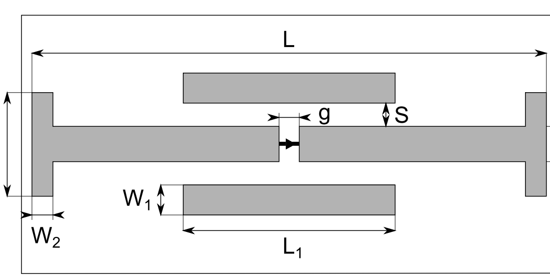

Fig. 1. Antenna Design. Dimensions are provided in Table I.

The design has been optimised with respect to the objectives using full wave simulation within CST Microwave Studio [8]; the resulting parameter values are listed in Table I.

III. SIMULATION RESULTS

The theoretical performance of the antenna was analysed using CST Microwave Studio. Fig. 2 shows the simulated $|S_{11}|$

TABLE I
OPTIMISED DESIGN PARAMETERS

L	41.97 mm
L_1	17.25 mm
S	4.56 mm
g	1.67 mm
W	2.78 mm
W_1	2.39 mm
W_2	1.63 mm
t	8.39 mm

values between 2 GHz and 6 GHz.

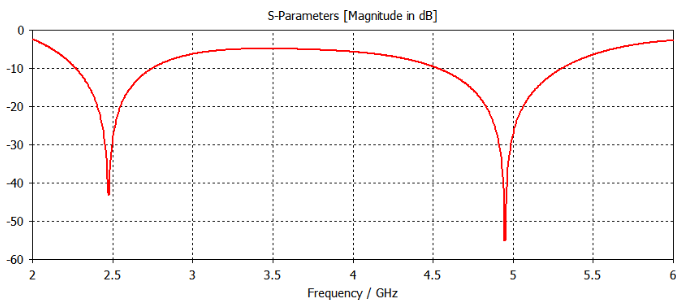

Fig. 2. Simulated $|S_{11}|$ values (dB)

At the fundamental frequency, the azimuthal radiation pattern is constant to within $\lesssim 0.1\,\mathrm{dB}$ (Fig. 3, 5), and even at the harmonic to within $\lesssim 1.2\,\mathrm{dB}$, as shown in Figures 4 and 6. Dielectric losses were found to be around 0.3 dB.

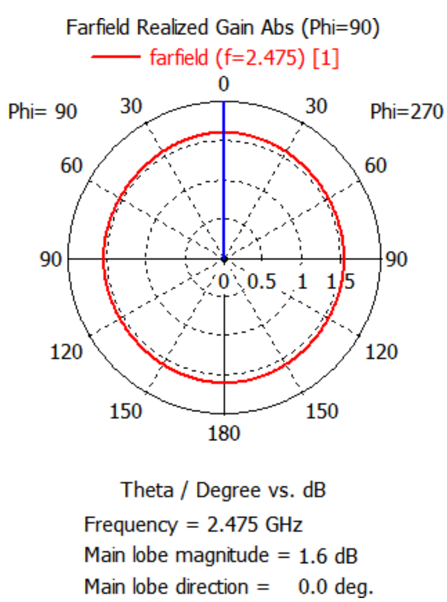

Fig. 3. Realised Gain at 2.475 GHz

IV. DISCUSSION

With $|S_{11}|$ less than $-40\,\mathrm{dB}$ for both, the fundamental and the harmonic frequency, and bandwidths ($|S_{11}| \leqslant -10\,\mathrm{dB}$) of 15.6% (4.53–5.30 GHz) at the fundamental and 19.4% (2.27–2.75 GHz) at the second harmonic, this antenna design is suitable for harmonic transponder applications which require highly efficient coupling between the antenna and the non-linear element, in this case a Schottky diode. For the final transponder design, the antenna will have to be matched to the actual impedance of the Schottky diode used [9]. One potential problem with the design is the effect of the animal on the resonant frequency of the transponder. This effect can be reduced by placing a layer of Styrofoam, or some low dielectric constant plastic material, between the animal and transponder. Some further retuning of the transponder antenna may be required depending on the way that the transponder is attached to the animal.

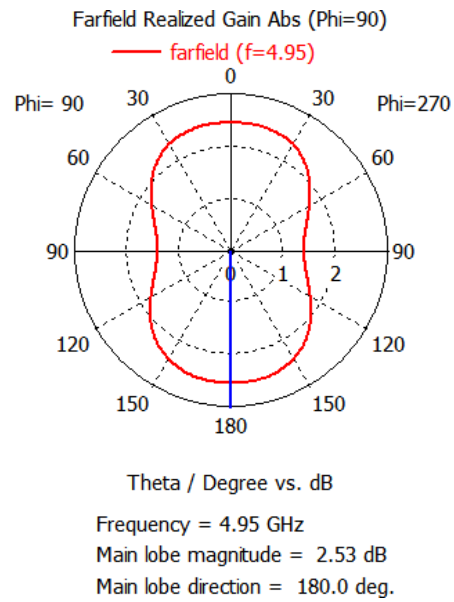

Fig. 4. Realised Gain at 4.95 GHz

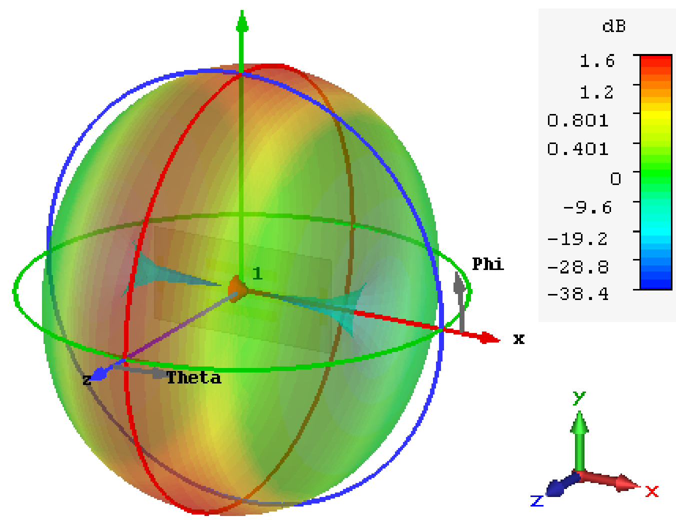

Fig. 5. Three-dimensional radiation pattern at 2.475 GHz

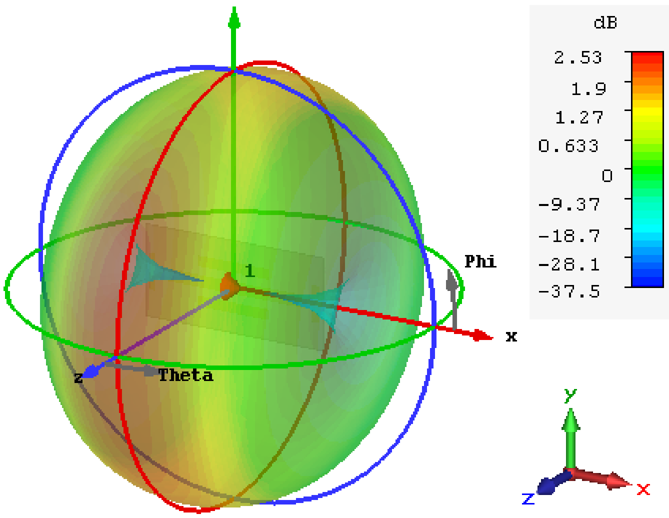

Fig. 6. Three-dimensional radiation pattern at 4.95 GHz

V. Conclusion

A dual-band dipole antenna with two additional parasitically coupled dipole elements for use in harmonic radar applications has been presented along with the results of a numerical simulation of its performance characteristics. The design was shown to give high radiation efficiency at both the fundamental frequency and the second harmonic. The design has the advantages of being compact and allowing independent control of the fundamental and second harmonic resonant frequencies.

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