Characterization of H2QL Antenna by Simulation

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***Abstract*— A novel wire antenna was named hybrid dual quad loop (H2QL) antenna. This paper attempted to characterize the H2QL antenna by simulating the antenna impedance, SWR and antenna pattern. EZNEC+ v5.0 was used to simulate the antenna parameters. The simulation was done at both UHF (431.35 MHz) and VHF (145.22 MHz) bands using three wire diameters (3.175, 6.35 and 9.525 mm). Simulation results and preliminary analysis were presented. Variant configuration was also simulated and the result was presented. Further study on other variants and performance of experiments were recommended.**

***Index Terms*—computational EM, hybrid antenna, EZNEC**

I. Introduction

The first antennas were made of wires. Michael Faraday experimented on electromagnetic radiation and used loop antenna to receive it. Wire antennas were as old as man-made radio wave propagation. As time passed, they became less popular. Novel wire antennas still blotted some professional publications now and then, but it rarely stirred up the general interest.

An antenna may be extended to three basic components : the driven element, the reflector, and the director. The set-up was especially true for wire antennas – dipole, loop, etc. That limitation (i.e., maximum of three basic components) had been the case for decades. This paper asked two different questions: *If there can be a fourth component, where will it be found? How will it influence the antenna parameters?*

II. Related Works

With reference to the direction of propagation, the reflector was placed at the back of the driven element and the director was placed at the front. There was one place where a fourth element could be located – at the same plane as the driven element. That possibility was investigated using the hybrid dual quad loop (H2QL) antenna shown in Fig. 1.

The H2QL antenna was made up of two coplanar quad loops – segments 1, 2, 3 and 4 for first loop, and segments 5, 6, 7 and 8 for second loop – and a single parasitic element called *pinoy* (marked as segment 9). All segments were of the same diameter and material. The *pinoy* was a novel parasitic element that is neither a reflector nor a director. This element was on the same plane as the two quad loops and was placed at the midpoint between the two quad loops parallel to segments 1 and 5.

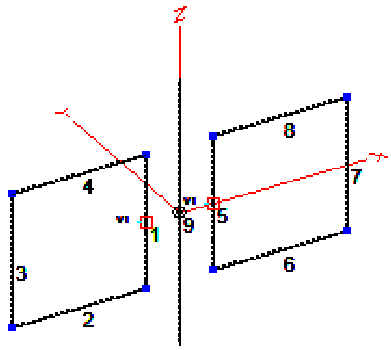

Fig. 1. Configuration of H2QL Antenna

Loop antennas were classified in [1] as either electrically small (total length ≤ 0.1λ) or electrically large (total length ≈ λ). The antenna under test measured exactly 1 λ as length of its perimeter. Consequently, the direction of propagation was normal to the plane of the loop.

A prior experimental study [2] served as impetus to this work. The experiments only measured the received signal strength and SWR values of the antenna using HP 8920A RF Communications Test Set equipment and Diamond SX-600 SWR meter, respectively. The current work dealt with antenna modeling using EZNEC+ v5.0 simulation software based on numerical electromagnetic code (NEC).

Gerald Burke was credited to be the main contributor for the development of the numerical electromagnetic code (NEC) that came out of Lawrence Livermore National Laboratory (LLNL). Since its introduction in the late 70s, the code had been adapted into several other antenna modeling software. Two of the most popular variants were the EZNEC by Roy Lewallen, a radio amateur, and the GNEC by Nittany-Scientific. Both variants had been used for the simulation needs of graduate theses and professional publications such as in [3] and [4] for EZNEC and in [5] and [6] for GNEC.

NEC presumed round wire antenna elements that are thin relative to the element length. This presumption limited what types of antenna structures or configuration can be replicated. This presumption, though, worked well with the antenna under test. Unfortunately, no working rule of thumb had been found in what possibly is the limit of the expression "*thin relative to the antenna length*". Nevertheless, rules had been established on the ratio between the smallest division of a single straight wire element (known as wire segment in the software) and the diameter of the wire element. Much more could be learned from [7] and [8].

An antenna manufactured by BAZ Spezialantennen [9] sounded similar to the H2QL antenna introduced here. It was named *hybrid double quad antenna*. Figure 2 showed the actual configuration of the hybrid double quad loop. It was composed of two quad antennas oriented like a diamond. One vertex from each quad was joined together and the feed point is located at that joint. Unfortunately, BAZ Spezialantennen website did not show clearly how the feed point was actually connected – whether it was shorted out or not.

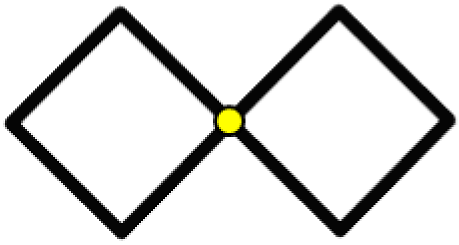

Fig. 2. Configuration of Hybrid Double Quad Antenna

III. Problem Settings

The parameters of the H2QL antenna remained largely unexplored. The objectives of this work were to design the configuration of this antenna for simulation, simulate its performance, and correlate the output data for approximate relationship of the antenna parameters being considered. Simulation was done through the use of EZNEC+ v.5.0 simulation software based on numerical electromagnetic code – version 2 (NEC2) with calculating engine NEC-2D at ground type of free space.

Scope and Limitations

Aluminum alloy 6063-T5 was assumed in the simulation. It had a resistivity of 3.2 x 10^8 Ω·m and a relative permeability of 1.000022. This was assumed as the characteristic of the wire since it was the best fit for the type of aluminum bars available locally in the Philippines. The test wire diameters used were 3.175, 6.35 and 9.525 mm. The test frequencies used were 431.35 MHz at UHF and 145.22 MHZ at VHF.

Hypotheses

Two hypotheses were forwarded : (1) the addition of a new parasitic element – called *pinoy* – placed in between two co-planar quad loops will significantly change the values of the standing wave ratio, impedance and gain of the antenna under test, and (2) the length of the *pinoy* element will also prove significant in determining the above performance parameters.

The name *pinoy* was chosen by the author for personal reason. It had no etymological connection to the function of that particular parasitic element. As such, it should be treated simply as a label.

IV. Results and Discussions

Figure 3 showed that standing wave ratio is dependent on the size of the wire. This relationship was more pronounced at higher frequencies. The results, though, was based on the assumption that the device using the antenna had a 50-Ω resistance. This was the case for other parameters under test.

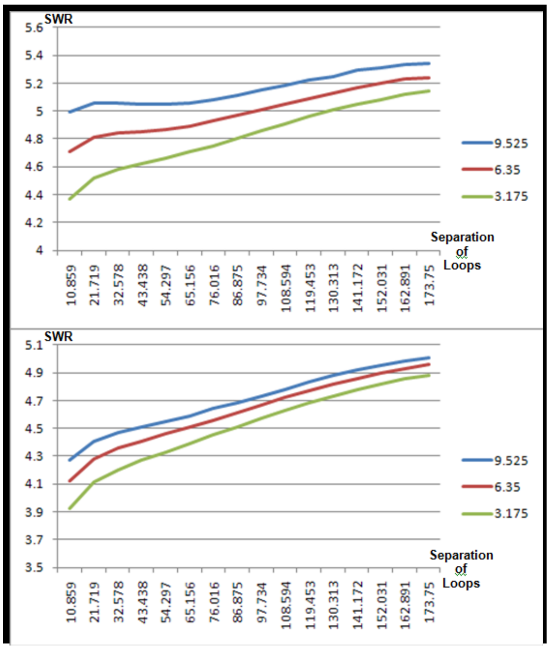

Fig. 3. SWR of the Antenna without Pinoy at UHF (top) and VHF (bottom)

Figure 4 showed that impedance is dependent on the size of the wire. Again, it was more pronounced at higher frequencies. At certain distance of the separation of loops, the diameter of the wires became insignificant.

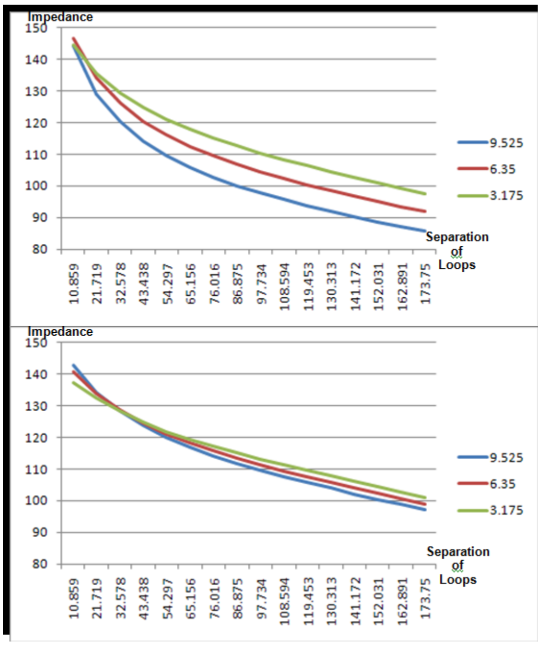

Fig. 4. Impedance of the Antenna without Pinoy at UHF (top) and VHF (bottom)

Figure 5 showed that the wire diameter was insignificant in the determination of antenna gain. Nevertheless, the graph of each wire diameter seemed to be quite linear.

In addition, all three parameters started off at lower values in the VHF band compared to the measurements at the UHF band. The perimeter of the loop antenna at both bands is equivalent to one wavelength of each designated frequency.

The VHF set-up allowed for better accuracy since the ratio between length of wire segment and diameter of the wire is larger due to longer wavelength at that band – a condition for better accuracy when using numerical electromagnetic code (NEC) as stated in [10] and [11]. Throughout all the simulation runs, the ratio between the length of the wire segment and the diameter of the wire is kept relatively constant.

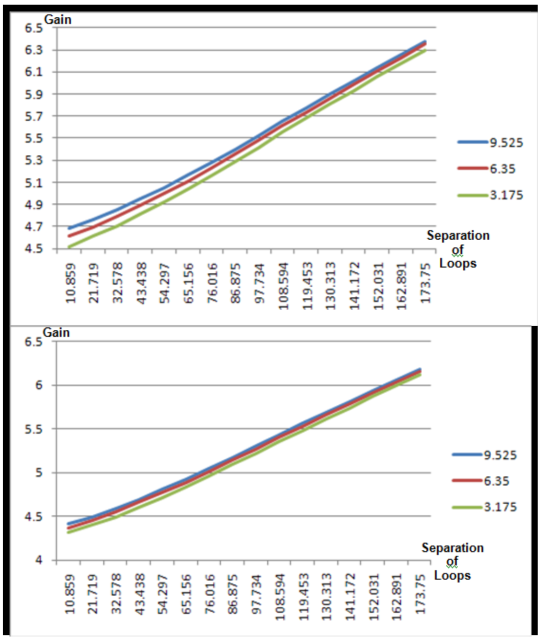

Fig. 5. Gain of the Antenna without Pinoy at UHF (top) and VHF (bottom)

Figures 6, 7, and 8 showed the SWR, impedance, and gain – respectively – of the antenna at different *pinoy* lengths and separations of loops. The *pinoy* was incrementally increased by 0.03125λ. The length started at 0.03125λ and ended at 0.5λ.

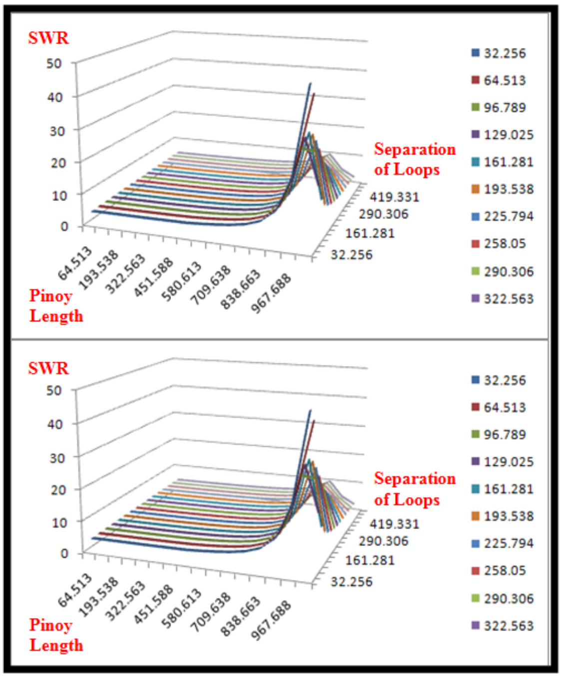

Fig. 6. SWR of the Antenna with Pinoy at UHF (top) and VHF (bottom)

Smaller SWR was obtained with wider separation of the loops and longer *pinoy* length. Highest SWR is found at *pinoy* length of about 0.4375λ with the narrowest separation of the loops. Lowest SWR is found at the longest *pinoy* length with the widest separation of loops. The maximum *pinoy* length is set at 0.5λ.

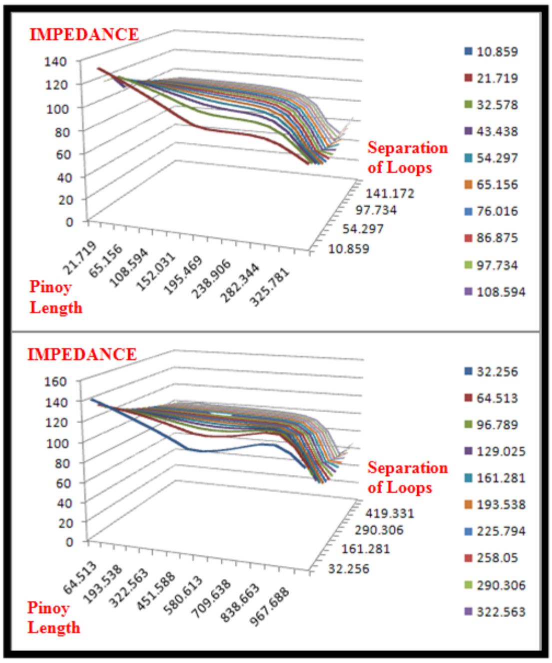

Fig. 7. Impedance of the Antenna with Pinoy at UHF (top) and VHF (bottom)

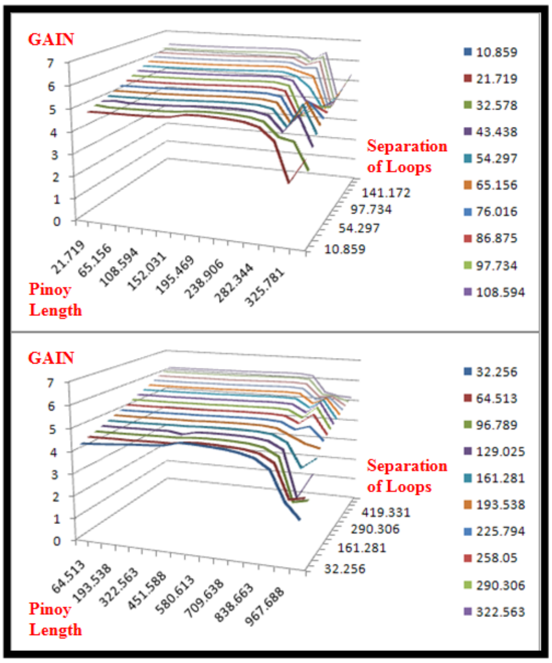

Fig. 8. Gain of the Antenna with Pinoy at UHF (top) and VHF (bottom)

The lowest impedance was attained at *pinoy* length of about 0.4375λ at the widest separation of loops. Unfortunately, the phase shift due to the presence of reactive components was not part of the considered results shown in Fig. 7. It would have given a better understanding on how to design the impedance-matching network and how much effective power was transmitted by the antenna and how much was lost along the transmission line.

If taken separately from the other performance parameters, higher gain was supposed to define a better antenna. The received signal was better amplified at higher gains – resulting to better signal reception. Gain was used here synonymous with directivity. More rapid gain change happened when separation of loops was gradually increased than when *pinoy* length was gradually increased as illustrated in Fig. 8. From the results shown, the best gain was obtained from *pinoy* length at around 0.3125λ and the separation of the loops at around 0.25λ. Gain increased almost linearly as separation of loops and/or *pinoy* length increased – until the *pinoy* length reached about 0.375λ. The variation of the gain from this length up to 0.5λ was yet to be described mathematically.

The seemingly rapid change of the parameters at *pinoy* lengths between 0.375λ and 0.5λ stirred the interest of the researcher to look elsewhere for other clues. Interesting results were observed when looking at the propagation pattern of the antenna. Figure 9 showed a sample of the propagation patterns as *pinoy* length was gradually increased while the separation of loops remained constant. As can be gleaned from the last row (especially the first two patterns), the direction of propagation had shifted.

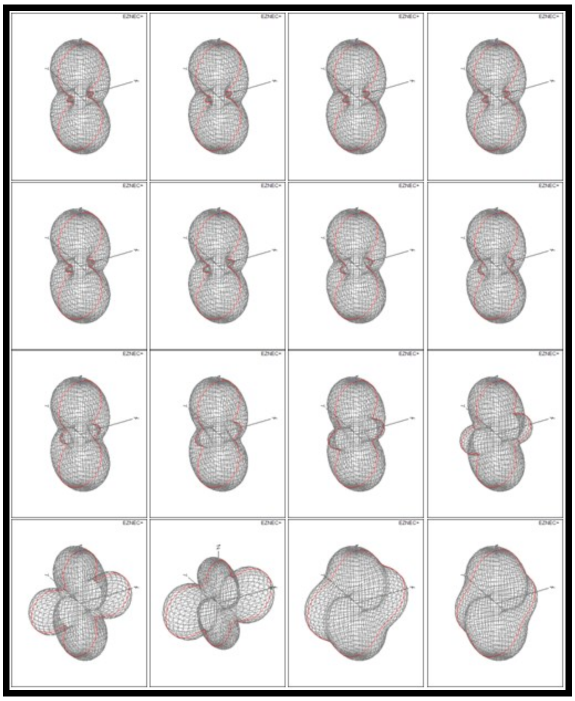

Fig. 9. Propagation Patterns at Different Pinoy Lengths

When a single-wire reflector was added to the antenna, an interesting propagation pattern resulted. Figure 10 showed the resultant pattern when the separation of loops was at 0.0625λ, *pinoy* length is at 0.4375λ, reflector length is at 0.5λ, and the distance between the reflector and *pinoy* is at 0.09375λ. The antenna was operated at the identified UHF frequency.

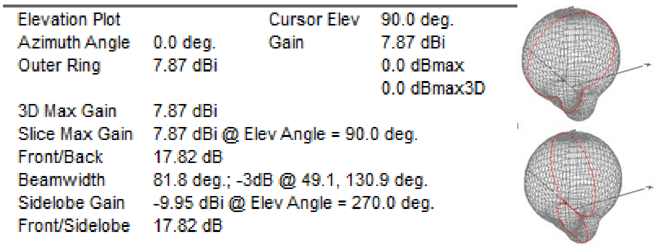

Fig. 10. H2QL Antenna with Wire Reflector

V. Conclusion and Recommendations

The H2QL antenna showed some promise as a directional antenna and some probability of being reconfigurable. The *pinoy* exhibited an influence to all antenna parameters under test. The most significant influence happened when the *pinoy* length is between 0.375λ and 0.5λ.

With the addition of a wire reflector and/or a wire director, the antenna under test may exhibit other interesting variations of the parameters. It is therefore recommended that a study on H2QL antenna with a wire reflector and/or director be done at different lengths of the reflector/director, *pinoy* and separation of the loops. Finally, it is recommended that the antenna under test is used in an array.

References

[1] Glen S. Smith. “Loop Antennas” in Antenna Engineering Handbook, 4th ed., John L. Volakis (ed.), New York : McGraw-Hill, 2007, pp. 5-1 – 5-25.

[2] Erwin B. Daculan, “Short Experimental Study of a Hybrid Dual Quad Loop Antenna for VHF/UHF Commercial TV Broadcast,” 25th SPP National Congress, Laguna, Philippines, 2007.

[3] Thomas Moses. “A Survey of Antennas for Wireless Communication Systems.” M.S. Thesis, Florida State University, United States, 2008.

[4] M. Salmi. “Phasing of a HF Antenna Array.” M.S. Thesis, University of Oulu, Finland, 2007.

[5] Timothy L. Pitzer and James A. Fellows. “Linear Ensemble Antennas Resulting from the Optimization of Log Periodic Dipole Arrays Using Genetic Algorithms.” IEEE Congress on Evolutionary Computations, Sheraton Vancouver Wall Centre Hotel, Vancouver, BC, Canada, 2006.

[6] Kho Swee Jin, John C. McEachen and Gurminder Singh. “RF Characteristics of Mica-Z Wireless Sensor Network Motes.” Internet : IEEE Xplore, 2006 [18 December 2012].

[7] Kho Swee Jin, John C. McEachen and Gurminder Singh. “RF Characteristics of Mica-Z Wireless Sensor Network Motes.” Internet : IEEE Xplore, 2006 [18 December 2012].

[8] Steve Stearns, “Antenna Modelling for Radio Amateurs,” ARRL Pacificon Antenna Seminar, San Ramon, CA, 17-19 October 2008, Internet : FARS [18 December 2012].

[9] BAZ Spezialantennen, www.amateur-radio-antenna.com/amateurradio-antenna/double-quad-antenna/index.php

[10] G.J. Burke and A.J. Poggio, “Numerical Electromagnetics Code (NEC) : Method of Moments – Part II : Program Description – Code,” Lawrence Livermore National Laboratory, USA, Internet : LLNL [18 December 2012].

[11] G.J. Burke and A.J. Poggio, “Numerical Electromagnetics Code (NEC) : Method of Moments – Part III : User’s Guide,” *ibid*.