# A Simple and Practical Impedance Matching Network for Quadrifilar Helix Antenna

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***Abstract*—In this work, a new impedance matching network is designed for Quadrifilar Helical Antenna (QHA). It is shown that the proposed network, which is realized by microstrip transmission line, can efficiently match the input impedance of the QHA to the required impedance at a narrow frequency band. The measurement results are presented to verify the quality of the network.**

## I. INTRODUCTION

Quadrifilar Helical Antenna (QHAs) has been used for many applications such as Low Earth Orbit (LEO) satellites due to its miniature structure and radiation patterns. The QHA should be fed correctly to achieve suitable radiation characteristics. In general, the Quadrifilar Helix Antenna consists of four wires wound around an imaginary cylinder (or real cylinder in some cases) and fed with quadrature phases. One simple way to feed the antenna is the direct method [1]. In this method, 3 couplers (two 180- degree and one 90-degree hybrid) are used to produce the required phases. By means of the direct method, the antenna is fed from four points. Although this mode is simple, the requirement of three hybrid coupler increases the size and the weight of the antenna. Another possible feeding method is to use balun technique. The balun is used to feed a balanced antenna by an unbalanced coaxial cable. Since the QHA consists of two bifilar, two baluns are required as shown in Fig.1. One concerning about QHA is the impedance matching. The input impedance of this antenna varies sharply with frequency due to the resonance nature of the QHA. Therefore, the desirable input impedance may not be achieved easily. In addition, the antenna input impedance is affected by fabrication imperfections. Therefore, the impedance matching of the QHA has been concerned by a few authors and some methods have been suggested to match the input impedance of the antenna [2]-[5].

In this paper, a practical and simple impedance matching network for the QHA with balun feeding method is discussed. It is shown that the proposed network can be used to match the QHA impedance at a specific frequency band.

## II. STRUCTURE OF THE ANTENNA

Fig. 2 shows the proposed impedance matching network of the QHA. The network consists of a quadrature hybrid coupler to produce the required 90-degree phase shift for feeding, and a $\lambda_g/4$ transformer line for impedance transforming where $\lambda_g$ is wavelength at the central frequency.

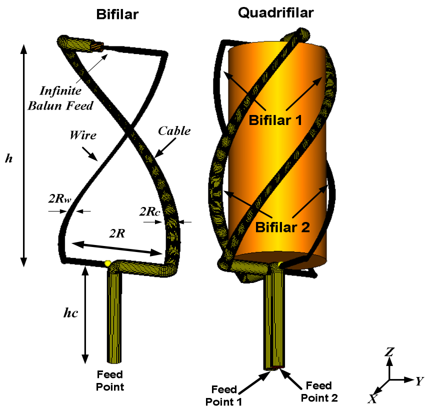
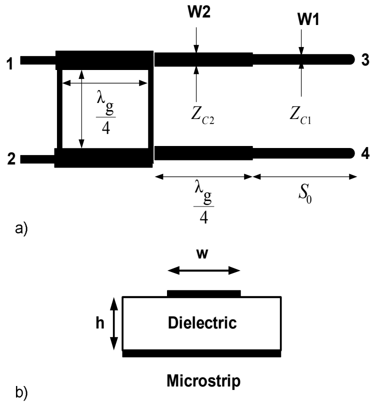


Figure 1. The geometry of the QHA with an infinite balun.



(b)

Figure 2. The feeding network realized by microstrip transmission lines. a) The hybrid coupler with $\lambda_g/4$ transformer and extended length $S_0$. $W_2$ and $Z_{c2}$are the width and characteristic impedance of the transformer. b) The microstrip parameters

There are other possible methods to obtain two equal powers with 90-degree phase difference such as using power divider with phase shifter. However, in this work the hybrid 90-degree is preferred due to its efficiency.

The $\lambda_g/4$ wavelength transformer is used to transfer the real impedance value [6], however, the input impedance of the

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QHA is generally complex. Thus, a specific length of the feeding cable, $S_0$, is used at the beginning of the network to achieve the real impedance in the center frequency. Then, the obtained real impedance can be transformed to the desirable impedance by the transformer.

Firstly, $S_0$ should be found to estimate the real value of the input impedance which is denoted as R□$_l$. According to [7], for low loss transmission line, the input impedance is calculated as the following:

$$
\begin{gathered}
Z_l' = \frac{Z_l + jZ_c\tan(x)}{Z_l + Z_c\tan(x)}, \\
Z_l = R_l + jX_l\,, \\
x = \beta S_0\,, \\
\beta = \frac{\omega}{c_0\sqrt{\varepsilon_{reff}}}
\end{gathered} \qquad (1)
$$

where $Z_{in}$, $Z_c$, and $Z_L$, are input, characteristic and load impedance, respectively. $\varepsilon_{reff}$ denotes the effective dielectric constant of the microstrip transmission line. In order to calculate $S_0$, the imaginary part of equation (1) is set to zero as follows.

$$-Z_cX_l tan^2(x) + \left({Z_c}^2 - {X_l}^2\right)tan^2(x) + Z_cX_l - R_l^2 = 0\,, \quad (2)$$

$S_0$ is calculated from equation (2). The characteristic impedance and effective dielectric constant of the transmission line can be calculated according to [7].

## III. SIMULATION AND MEASUREMENT RESULTS

In order to verify performance of the matching network, it is used to match a sample QHA. After fabrication the sample antenna, the antenna input impedance and mutual coupling between the ports are measured. Fig. 3 shows the measured mutual coupling between the input ports. Mutual coupling is less than -30dB which is fairly weak and can be ignored. The measured input impedance of the antenna (one bifilar of the antenna) is depicted in Fig. 4. It is obvious that impedance matching is necessary.

To realize the feeding network for the designed QHA, FR4 substrate ($\varepsilon_r$=4.9) is selected with h=0.5mm and $W_1$=0.5mm, so $Z_{c1}$=67.5Ω and $\varepsilon_{reff}$=3.49 are calculated [7]. By these values, two positive solutions of equation (2) are x=0.626 and 2.2 which lead to $S_0$=6.4mm and 22.5mm, respectively. In this work, we choose the second length. Hence, R□$_l$=23Ω is obtained. For the $\lambda_g/4$ transformer, the transformed impedance is achieved by

$$R_{in} = \frac{{Z_c}^2}{R_l'} \qquad (3)$$

where $R_{in}$ is the desirable input impedance. The characteristic impedance of the transformer part $Z_{c2}$ =34.5Ω is calculated from (3) and then $w_2$=1.7mm is obtained.

Measured scattering parameters of the network and simulation results obtained from Microwave Office modeling are shown in Fig. 5. The curves are in good agreement but there is a little difference due to the tolerance of the dielectric permittivity of the substrate and some imperfections in fabrication of the QHA structure. As shown in Fig. 5, $S_{21}$ (or $S_{12}$) is less than -20dB with bandwidth of 10MHz at 2.5GHz and $S_{11}$ is better than -35dB.

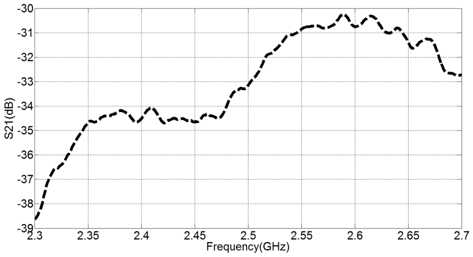

Figure 3. Measurement of the mutual coupling between bifilar1 and bifilar2

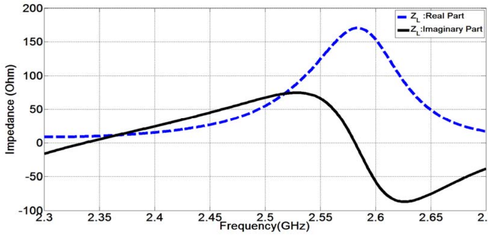

Figure 4. Measurement results of the antenna input impedance (bifilar1)

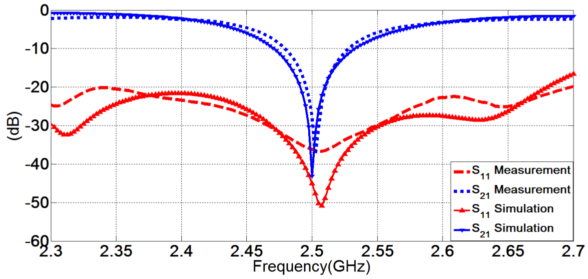

Figure 5. Simulated and measured scattering parameters of the matching network for the sample QHA

## REFERENCES

[1] R. Bricker, and H. Rickert, “An s-band resonant quadrifilar antenna for satellite communication,” Antennas and Propagation Society International Symposium, vol. l2, pp. 78-82, Jun. 1974.

[2] M. Hosseini, M. Hakkak, and P. Rezaei, “Design of a Dual-Band Quadrifilar Helix Antenna,” IEEE Antennas Propag. Lett., vol. 4, pp. 39-42, 2005.

[3] A. Chapari, Z. H. Firouzeh, R. Moini, and S. H. H. Sadeghi. “A low weight s-band quadrifilar helical antenna for satellite communication,” in 13th International Symposium on Antenna Technology and Applied Electromagnetics and the Canadian Radio Sciences Meeting, Alberta Canada, 2009.

[4] M. Notter, K. M. Kean, “Impedance Matching Arrangment for Quadrifilar Helix Antenna,” Electron. Lett., vol. 38, April 2002.

[5] D. Lamensdorf; M.A. Smolinski, ” Dual-band quadrifilar helix antenna,” IEEE Antenna and Propag. Society International Symposium, vol. 3, pp. 488-491, 2002.

[6] C. A. Balanis, Antenna Theory, Analysis and Design, 2ndед, New York: Wiley, 1996.

[7] D. M. Pozar., Microwave Engineering, 3ndеd, New York: Wiley, 2005.