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GA Based Real Frequency Technique for Antenna Broadband Matching

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GA Based Real Frequency Technique for Antenna Broadband Matching

Zhixun Huang[a, *] and Hu Yang[b]

National University of Defense Technology, Changsha, Hunan, China
E-mail: [a, *]huangzhixun12@nudt.edu.cn, [b]yanghu@nudt.edu.cn

Abstract. In this paper, the genetic algorithm is used as the optimization algorithm in real frequency technique for antenna wideband matching. A broadband matching network for an inductive whip antenna is designed by using genetic algorithm to optimize the dividing point impedance function, and the dividing point admittance function is optimized for a capacitive monopole. The achievable matching circuits are simulated by ADS and the results agree well with the optimized ones. Simulated results show that the matching networks increase the bandwidth of the antennas, verifying the effectiveness of the technique.

1. Introduction

Wideband impedance matching technique are widely used in RF and microwave systems which can greatly increase transducer power of the system. Within all wideband impedance matching technique, the real frequency technique has the advantages of high precision, good convergence and easy to implement in engineering.

Unlike other impedance matching technique, the real frequency technique does not require a default network topology which may not be the optimal topology. In this technique, the network topology is synthesized by its dividing point function. The same dividing point function can be synthesized by different networks, so the matching network can be designed to be an easy-to-implement structure in engineering. Despite these advantages, the matching performance of the technique is not so effective at first and it has been improving.

The real frequency technique was first proposed by H.J. Carlin in 1977 for wideband passive matching [1]. After that, the technique has been widely used in matching network design [2], [3]. Nowadays, real frequency technique is simplified and applied in antenna design for wideband operation [4]- [6]. In order to pursue better performance, some researchers begin to use different optimization methods in the technique [7].

This paper improved the real frequency technique by applying genetic algorithm (GA) to optimize the dividing point function. The GA based real frequency technique was implemented on antenna broadband matching. Two examples of designing matching network using the dividing point impedance function and the dividing point admittance function were given.

2. GA Based Real Frequency Technique

Provided the impedance of the antenna to be matched is Z_l, and the impedance of the dividing point from the antenna to the matching network is Z_q, then the transducer power gain (TPG) is

$$TPG=\frac{4R_q(w)R_l(w)}{\left[R_q(w)+R_l(w)\right]^2+\left[X_q(w)+X_l(w)\right]^2} \tag{1}$$

Where R_l, X_l is the real part and imaginary part of Z_l, and R_q, X_q is the real part and imaginary part of Z_q. If the real frequency data Z_l is given, TPG is determined by dividing point impedance Z_q or admittance Y_q. In order to promise the optimized matching network can be realized by ladder network which is easy to implement in engineering, only the real part of the dividing point function is optimized and the imaginary part can be obtained by the real part using the method of Gewertz.

For wideband matching of antenna, it is necessary to extract the sampling points in a wide frequency band, and optimize the matching characteristics in these frequency points. The least squares method was used to optimize the TPG before, but it was found that genetic algorithm had better performance in this technique as it searched for the global optimal solution rather than the local optimal solution. Moreover, GA cost less time in computing and its convergence was better.

Because the sampling frequency points are discrete, it is generally necessary to use a rational function that can be realized to fit the discrete optimized dividing point function. The rational function of the real part of the dividing point function used in this paper is

$$R_q\left(w\right)=\frac{A_0 w^{2k}}{1+B_1 w^2+\cdots+B_n w^{2n_s}} \tag{2}$$

With R_q obtained, according to the properties of analytic functions, the imaginary part of Z_q can be found using the method of Gewertz [8]. After deriving the expression of the dividing point function Z_q(s), it can be regarded as a two-port lossless network terminated with a 1-ohm resistance, which can be transformed into a continuous fraction by rolling division. The topology structure of the *n* order ladder network terminated with 1-ohm source is shown in Fig. 1. After performing anti-normalization on these parameters, the actual parameters of the matching network can be obtained.

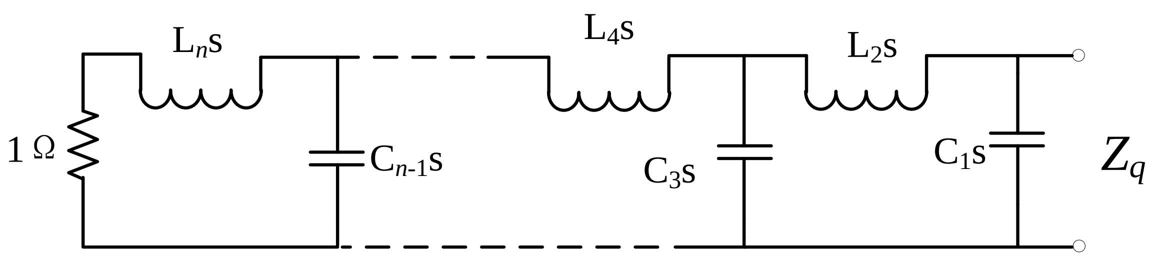

Figure 1. Ladder network of *Zq*.

3. Wideband Antenna Matching Network Design

3.1. Impedance Function Matching

In this section, dividing point impedance function and the dividing point admittance function are used respectively to optimize the TPG of two antennas. When the equivalent impedance of the antenna is capacitive, it is better to use the dividing point admittance function. Conversely, when the equivalent impedance of the antenna is inductive, dividing point impedance function is more suitable.

The first antenna to be match is a dual band UHF whip antenna with its reflection coefficient less than -10 dB in 28.3~30.5 MHz and 37.5~40.6 MHz. The GA based real frequency technique was implemented to optimize the TPG of the antenna from 27.5 MHz to 39.5 MHz. The GA population size was set as 50 and the generation was set as 500.The TPG of the whip antenna is shown in Fig.2, where the blue dash line is the TPG before matching and the red line is the optimized TPG by real frequency technique. It can be seen that the TPG of the matched antenna has been significantly improved in 32~39MHz. The high frequency band of the antenna moves closer to the low frequency band, and the match performance between the two bands becomes better. The optimized dividing point function of the matching network is

$$Z_q = \frac{2.2391s^2 + 1.1585s + 1}{4.1247s^3 + 2.1341s^2 + 3.7749s + 1} \tag{3}$$

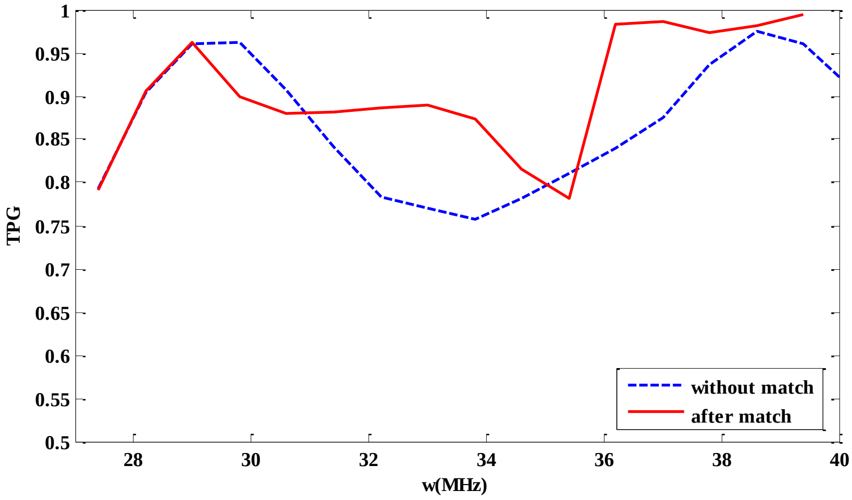

Figure 2. TPG of the whip antenna.

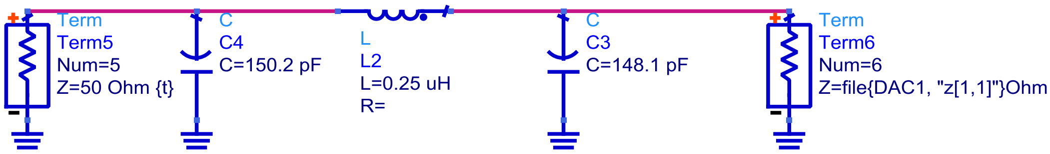

Figure 3. Schematic of the matching network.

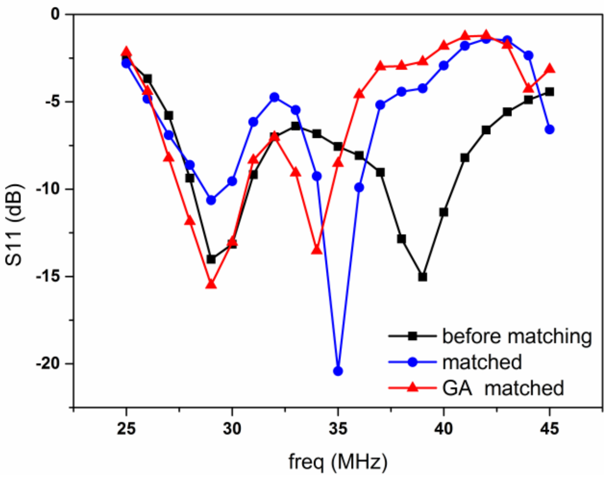

Figure 4. Reflection coefficient of the antenna before and after matching.

By applying Eq.3 and Eq.4 to Eq.5, the parameters of the matching network can be obtained. The achievable network simulated via ADS is shown in Fig.3, where the right port terminates with the antenna and the left term is 50-ohm term. The simulated results of the unmatched antenna, least squares based technique matched one and GA based technique matched one are shown in Fig.4, indicating that the GA based real frequency technique improves the matching performance in broadband. The results are consistent with those optimized by real frequency technique, which verifies the effectiveness of the technique.

3.2. Admittance Function Matching

In section 3.1, a whip antenna was matched by means of real frequency technique using dividing point impedance function as the antenna was inductive. In this section, a capacitive monopole was matched using dividing point admittance function. The monopole was 1.75 meters high and its ground radius was 0.85 meters, whose resonant frequency was 198 MHz with 30 MHz bandwidth.

Applying real frequency technique, the whole frequency band was dividing into 5 bands from 0 to 500 MHz, and the passband was set between 50~450 MHz. 21 frequency points were selected in the passband for optimization, and the network complexity n_s was set as 3. The TPGs of the monopole before and after matching are shown in Fig.5. It indicates that the optimized TPG has been improved in almost the whole passband. The optimized dividing point function of the matching network is

$$Y_q = \frac{2.5443s^2 + 1.3835s + 1}{5.6518s^3 + 3.0733s^2 + 4.0604s + 1} \tag{1}$$

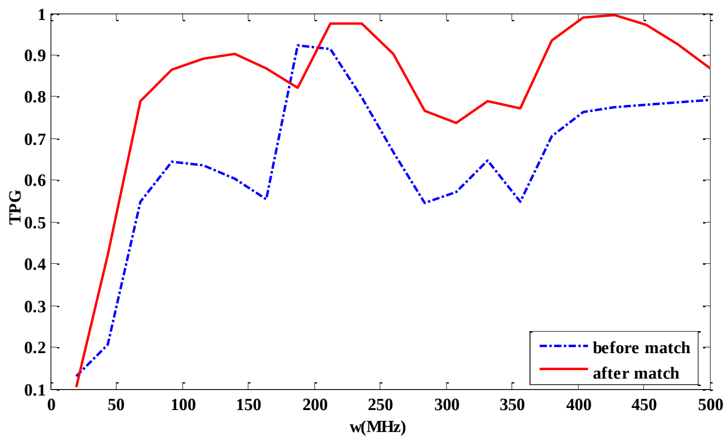

Figure 5. TPG of the monopole.

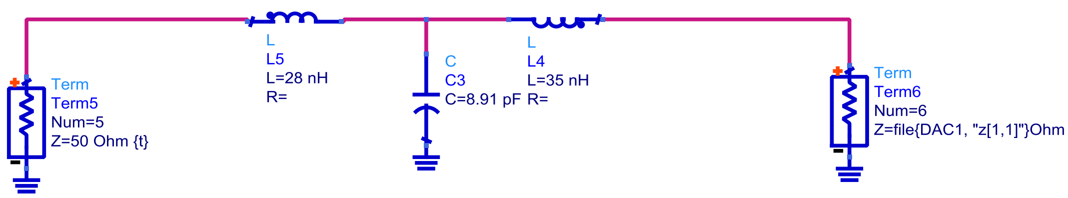

Figure 6. Schematic of the matching network.

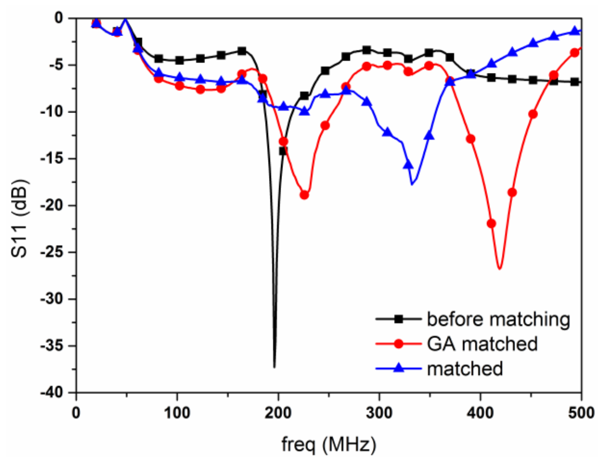

Figure 7. Reflection coefficient of the antenna before and after matching.

The achievable network simulated by ADS is shown in Fig.6 and the simulated reflection coefficient is shown in Fig.7. It indicates that the matching network optimized by the GA based real frequency technique not only improves the matching performance by introducing a new resonance point at high frequency, but also widens the original resonant bandwidth. The matching network designed by GA based real frequency technique is effective. The least square based real frequency technique also improves the matching performance in broadband, but it is not as well as the GA based one. The performance of the frequencies below the original resonant frequency have also been improved, even it is not obvious due to Bode-Fano limitation [9].

4. Conclusions

This paper applies GA in real frequency technique for antenna wideband matching network design. According to the impedance of the antennas, dividing point impedance function and admittance function are used to design matching network of a whip antenna and a monopole respectively. Simulated result shows that the TPG of the whip antenna after matching network improves in 32~39MHz and the TPG of the matched monopole improves in 50~470 MHz. The matching networks obtained by the technique were simulated through ADS, and the results are consistent with the optimized ones. The correctness of the GA based real frequency technique and the practicability of its application in antenna broadband matching are verified.

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