Design and Optimization of a New Power Monitor with Small Size

ABBAS ALI LOTFI NEYESTANAK
Electrical Engineering
Islamic Azad University-Branch of Ray
Ghom Highway, Tehran
I.R.IRAN

ALI HOMAII
Electrical Engineering
Islamic Azad University-Branch of Ray
Ghom Highway, Tehran
I.R.IRAN

MASOOD KHOSROSHAHY
Electrical Engineering
Iran University of Science & Technology
Narmak, Tehran
I.R.IRAN

MOHAMMAD MIRHOSAINI
Electrical Engineering
Islamic Azad University-Branch of Ray
Ghom Highway, Tehran
I.R.IRAN

Abstract: -This paper describes the theory of the operation of directional coupler and presents some information about designing a very flat coefficient coupling. A power monitor is designed and then optimized for UHF band using genetic algorithm with fractal coding. In this paper, a transformer element is used to obtain a very flat coupling factor and then it is fabricated and compared with experimental results. Using two elements and genetic algorithm optimization, an outstanding result in size and coupling factor has been achieved. The measured results of the optimized power monitor validate a high compatibility between the simulation and the real experience.

Key-Words: - Power Monitor, Directional Coupler, Genetic Algorithm, Fractal Coding, Wide Band, UHF.

1 Introduction

Directional couplers have found numerous applications in microwave networks and systems. They perform a variety of functions such as splitting and combining power in mixers, hybrid power sampling of sources for level control, separating incident and reflected signals in network analyzers, and dividing power among a number of loads. In this paper, a directional coupler will be described and it is shown that the corresponding design has a wideband coefficient which is useful for AGC unit in transmitter.

As implied in the paper's title, all of the networks will be transmission line, TEM network strip line or microstrip line based. Directional couplers have the special property of coupling energy from a specific direction into a couple of ports. The coupled line couplers make use of the backward wave coupling principle: odd and even modes of the wave on the pair of the coupled lines travel at the same velocity with different characteristic impedances. The characteristic of a directional coupler can be expressed in terms of its coupling factor and directivity.

There are a lot of ways to design a wideband directional coupler, calculations of which are very difficult; but in this paper, with the information found in other papers about directional couplers, a directional coupler with multi element is designed to obtain a flat coupled factor and a weak coupling factor. Some methods which have been recognized in the past years by a number of authors have been employed [1], [2], [3].

Using genetic algorithm with fractal coding, a coupling factor of -40dB with $\pm 0.5dB$ tolerance is obtained. HP-HFSS software has also been used for simulation and design.

Due to the measureless number of variables and large number of output characteristics related to the antenna structure, antennas cannot be optimized by conventional techniques, which use gradient methods. Applications of genetic algorithms for optimization problems are widely known [4]. Their advantages and disadvantages in comparison with classical numerical methods are also known. The performance of the genetic algorithm is determined by the investigation and utilization of relationships throughout the run. This balance between the utilization of the whole solution space and the detailed searching of some parts can be modified to change the genetic algorithm operators (i.e. selection, crossover and mutation).

Fractal coding of parameters in genetic algorithm offers a choice to follow extremely complex structures in optimization [5, 6].

Maybe the largest obstruction in the way of using GA in electromagnetic, is the size of the jobs they try to attempt. In [6], a method of reducing the size of the parameter gene through a compressed fractal coding is discussed. In [7], a very flat directional coupler is reported. In this paper, a small dimension with very flat coupling and good matching is presented.

2 Directional Coupler

A round conductor is used to design this directional coupler. This is particularly good for weak coupling and high power application. Multi section coupler formulas are very difficult so even-and-odd mode is the best way to analyze this problem. It means that impedance of one is the admittance of the other. In this designing, we have two elements with round conductors.

$$Z_{0e} + Z_{0o} = \frac{120}{\sqrt{\varepsilon_r}}.\ln\frac{4b}{\pi d}$$
$$Z_{0e} - Z_{0o} = \frac{120}{\sqrt{\varepsilon_r}}\ln\cot an\frac{\pi s}{2b} \quad (1)$$

Coupling factor C is as shown:

$$C = \frac{Z_{0e}/Z_{0o} - 1}{Z_{0e}/Z_{0o} + 1} \quad (2)$$

Where Z_{0e} and Z_{0o} are the even and odd modes impedances and are discussed below. In order for the coupler to perfectly match to its terminating transmission line of Z_0 characteristic impedance, it's necessary that:

$$Z_0 = \sqrt{Z_{0e.}Z_{0o}} \quad (3)$$

The even mode impedance, Z_{0e}, is the characteristic impedance of a single coupled line to ground when equal currents are flowing in the two lines while the odd mode impedance, Z_{0o}, is the characteristic impedance with currents flowing in the opposite direction in the two lines. Values of Z_{0e} and Z_{0o} for a number of cross sections presented are given by:

$$Z_{0e} = Z_0.\sqrt{\frac{1+c}{1-c}} \quad (4)$$

$$Z_{0o} = Z_0.\sqrt{\frac{1-c}{1+c}} \quad (5)$$

Physical dimension necessary to produce the required even and odd mode impedance, Z_{0e} and Z_{0o}, could be obtained from (1).

When three sections of elements to obtain wideband coefficient exist, the following equations are employed:

$$(Z_{0e})_i = Z_0.\sqrt{\frac{1+c_i}{1-c_i}} \qquad i = 1,2 \quad (6)$$

$$(Z_{0o})_i = Z_0.\sqrt{\frac{1-c_i}{1+c_i}} \qquad i = 1,2 \quad (7)$$

Z_0 and Z_{0o} are the impedances of the even and odd modes in the coupled line normalized to the impedance of the input lines, and are related by:

$$Z_{0e}.Z_{0o} = 1 \quad (8)$$

Z_0 and Z_{0o} are obtained for each element and then the coupled line for the intended application could be designed.

3 Simulation and measurement Results

In this section, simulation results for more directional coupler samples with different dimensions are studied and then the best sample between the simulated sample and optimized sample is considered and at the end, these methods have been compared with each other.

In this directional coupler, two elements are used, calculations of which are in the related section. Dimensions of this directional coupler are related according to the impedances of each element and calculations of odd and even mode impedances which are renormalized with 50Ω. Radius and distance of lines (main line and the coupled line) and the dimension of cavity of coupler are shown in figure 1. In this figure, a directional coupler with three elements is designed using transformer theory and the coupling factor of this structure is shown in figure 2. This factor is flat with 0.25 dB tolerance but the dimension of this structure is very large so two small-lengthed elements have been used. In figure 3, a power monitor with two elements is shown which is used for simulation as well.

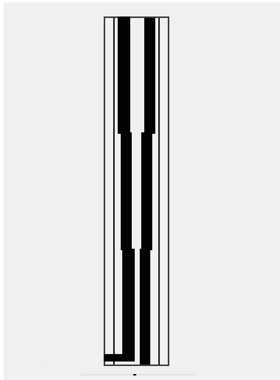

Figure1: Three-section directional coupler

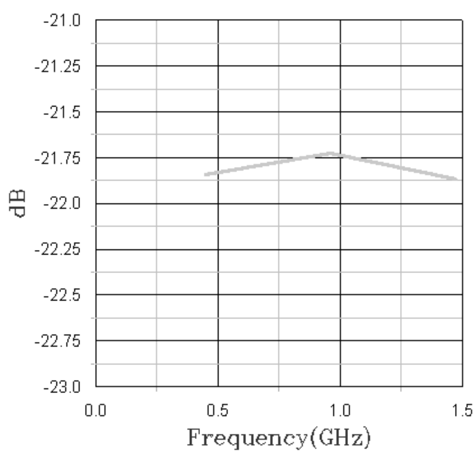

Figure2: Coupling factor of the three-section element

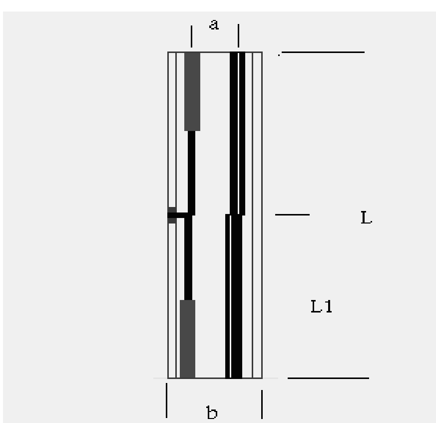

Figure3: Two-element power monitor

In this structure, two elements could be used to achieve best result using genetic algorithm optimization. The fractal coding method works by using a coding process, which describes the number of iterations, generator, randomness, and so on [5].

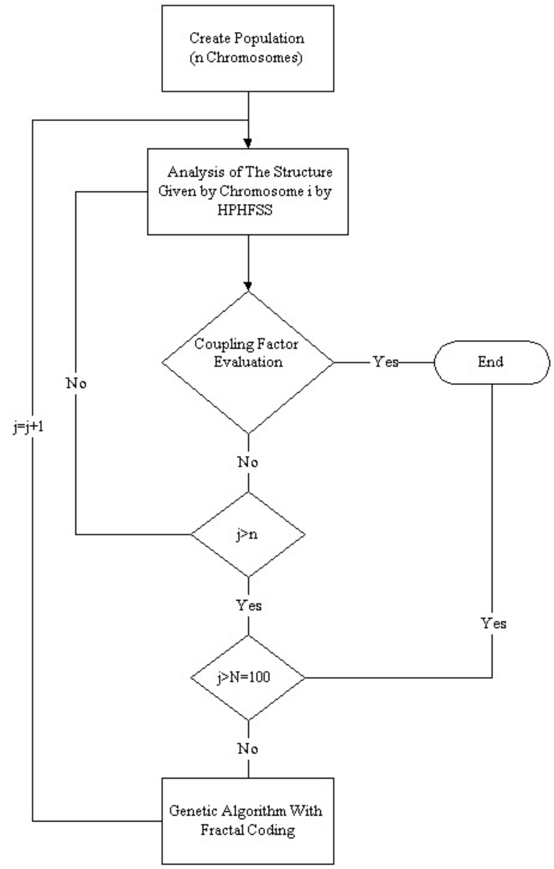

Figure 4: Flow chart of the optimization algorithm

Figure 4 shows the flowchart of the optimization algorithm. Now the best coefficients of this coupler simulated in computer are presented and compared with experimental sample made in the lab.

The first coefficient is the return loss of the input which is equal to the output. This factor is very good in the computer simulation and is shown in figure5.

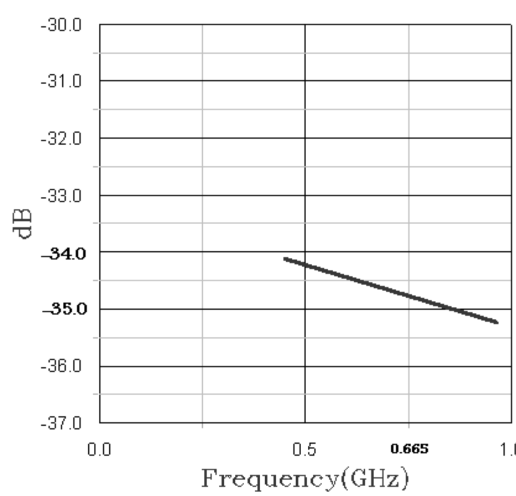

Figure5: Return loss of the two-element power monitor

This factor is presented to explain the reflected and forwarding powers in each structure. It has been used in all of the structures to compute the value of the forwarding and reflected powers which are related to each other with VSWR (voltage standing wave ratio). The second parameter is the coupling factor and is shown in figure 6.

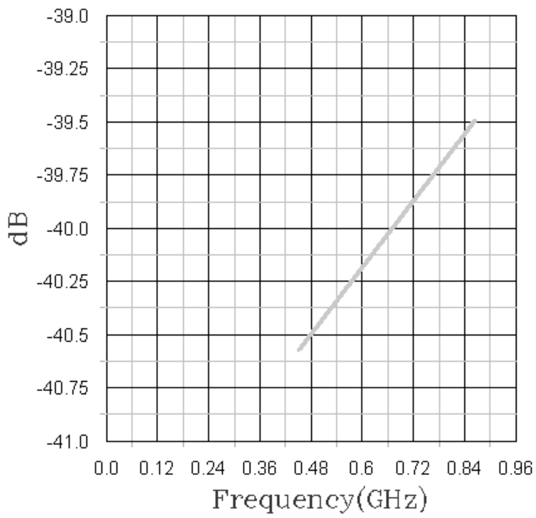

Figure 6: Coupling factor of this structure

Then the insertion loss of this structure is shown in Figure7. A brass has been used as conductor.

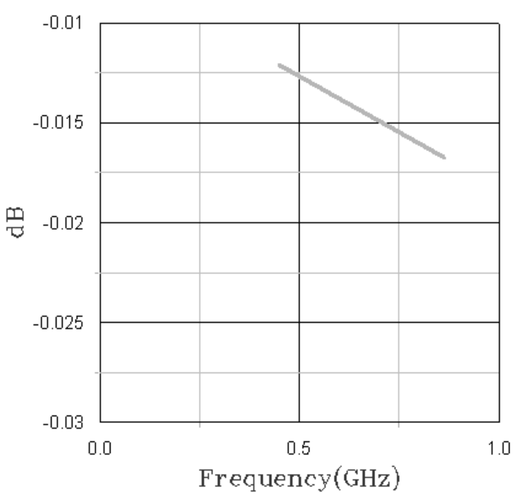

Figure7: Insertion loss of the two-element directional coupler

4 Test results

In this section, the testing and the measurement of the directional coupler have been described and compared with simulation results. The directional coupler which is made in the lab is shown and its various parameters have been measured with network analyzer for comparison with simulated results. Figure 8 shows the fabricated sample with two elements.

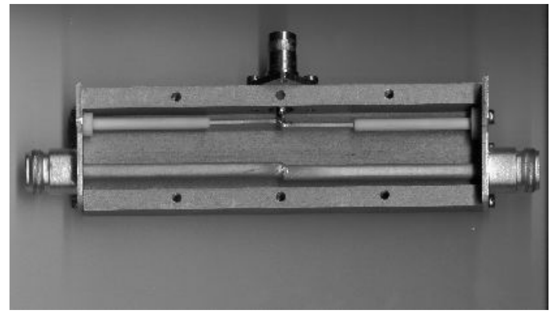

Figure8: Experimental power monitor

Various parameters such as coupling factor, return loss of this structure have been measured and depicted in the following figures. Coupling factor is shown in figure 9.

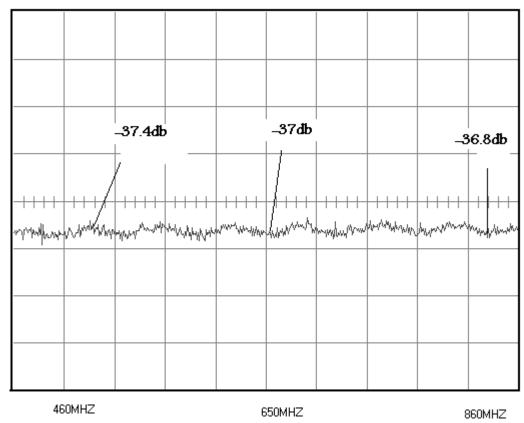

Figure9: Coupling factor of the experimental power monitor

Return loss of this structure is shown in figure 10. This factor is almost equal to the simulated parameter. The sample measurement results have been compared with simulation results in table 1. It is apparent that the experimental sample which is tested in the lab and the simulated one have close values. Although the dimensions of the experimental sample were chosen equal to the simulated structure dimensions but return and insertion losses are not close to the expected simulated sample losses and depend on the kind of brass and plating used and the variations of the dimensions. The advantage of this optimization is the fixed structure to fix the coupling factor for all of the UHF frequency bands.

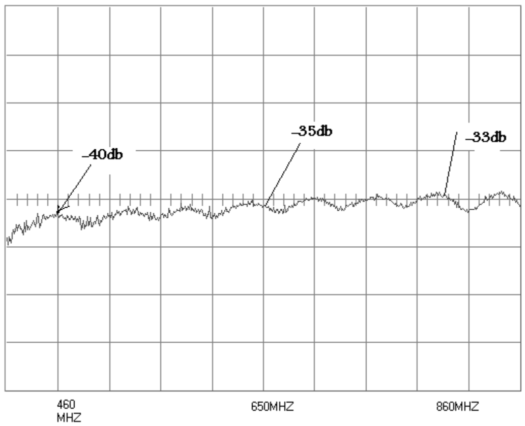

Figure10: Return loss of the power monitor

When the fixed coupling factor is achieved for all of the frequency bands, there is not any change of this factor resulting from other changes for example moving the coupler or changing the frequency. Power output of the antenna can be measured without turning off the transmitter.

Table 1: Comparison of the simulated and experimental sample values

Insertion loss	Return loss	Variation	Coupling factor	
-.015dB	-45dB	$\pm 0.5dB$	-40dB	Simulation
-0.03dB	$\geq -36dB$	$\pm 0.35dB$	-40dB	Measurement

5 Conclusion

In this paper, a directional coupler with wide bandwidth and small size was presented and optimized. In this coupler two elements could be used to get the best result using genetic algorithm optimization with fractal coding. The coupling factor and return loss of this structure have been measured. The measured results of the optimized directional coupler confirm a high compatibility between the simulation and the actual experience.

References:

[1] R. Levy, "General synthesis of asymmetric multi-element coupled-transmission-line directional coupler," IEEE Trans .on Microwave Theory and Techniques, vol .MTT -11, July 1963, pp. 226-237.

[2] B.M. Oliver, "Directional electromagnetic couplers," Proc IRE, vol.42, November 1954, pp.1688-1692.

[3] G. L Matthaei, L. Young, and E. M. T. Jones, "Microwave Filters, Impedance- Matching Networks and Coupling Structures". New York: McGraw Hill, 1988.

[4] Y. Rahmat-Samii and E. Michielssen, "Electromagnetic Optimization by Genetic Algorithms", New York, NY: Wiley, 1999.

[5] Cohen, N., 1997, “Genetic Antenna Optimization with Fractal Chromosomes”, Proceedings of ACES, 1997, pp. 305-308.

[6] Cohen, N., “Fractal Coding in Genetic Algorithm (GA) Antenna Optimization”, Proceedings of IEEE-APS/URSI, 1997, pp. 1013-1017.

[7] G. P Riblet, “A directional coupler with very flat coupling,” IEEE Trans. Microwave Theory Tech., vol. MTT-26, Feb. 1978, pp. 70–74.