

PC Tools for Radio Communications Engineering

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Abstract - In This Paper PC Tools for Radiocommunication engineering is described. This set of programs is used in teaching radiocommunications for 2nd grade students on the Post Secondary Technical School in Zagreb. Main properties of these programs are presented and parameters for each program are listed. The capabilities of the programs are analyzed. Some simulation results for real values of the parameters are given.

I INTRODUCTION

PC tools for Radio Communications Engineering is a computer program package directly oriented to radio communication engineering. It includes the ability to analyze networks, transmission lines, antennas and communication links. Its purpose is getting experience in the design and calculation of the communication circuits, where the circuits and their environment are not very complex, or the satisfactory results are obtained using an ideal model (in teaching, for example). The tools are to be implemented on IBM PC compatible machine in Microsoft QBASIC, utility available with every MS-DOS operating system.

The programs are organized into the general areas: phasor calculations, antenna design and analysis, propagation analysis, transmission line and two-port network analysis and matching, calculations of intermodulation frequencies produced by a set of transmitting frequencies.

II PROGRAM DESCRIPTION

A. Antenna design and analysis

The program named "Impedance of Folded Antenna" can be used to design folded dipole antennas. It calculates the input impedance of folded dipoles or monopoles. The folded antenna is a very popular wire antenna with good impedance properties and easy to construct. The folded dipole with equal radii of driven and parasitic conductors and half-wave length has an input impedance very close to that of a balanced 300 ohm transmission line.

The program named "Log-Periodic Antenna" can be used to design a log-periodic dipole array optimized for maximum gain. The input information required is the

bandwidth and the desired gain. The output includes the number of dipole elements required, the dipole elements length and spacings. The example given in the Table I is the result of the calculations for the antennas with 8 dB, 9 dB and 10 dB gain and operating frequency range from 50 MHz to 150 MHz. Such antennas should be constructed of 10, 13 and 18 dipole elements respectively and the output data from the program are listed in Table I. It is evident that the number of elements increase with increasing gain.

frequency range 50 - 150 MHz						
gain	8 dB		9 dB		10 dB	
elm. no.	length	space	length	space	length	space
1	3.58	0	3.42	0	3.25	0
2	2.89	1.02	2.95	1.07	2.97	1.10
3	2.33	0.82	2.54	0.92	2.71	1.01
4	1.87	0.66	2.19	0.80	2.48	0.92
5	1.51	0.54	1.88	0.68	2.26	0.84
6	1.22	0.43	1.62	0.59	2.07	0.77
7	0.98	0.35	1.39	0.51	1.89	0.70
8	0.79	0.28	1.20	0.44	1.72	0.64
9	0.64	0.23	1.03	0.38	1.57	0.58
10	0.51	0.18	0.89	0.32	1.44	0.53
11			0.77	0.28	1.31	0.49
12			0.66	0.24	1.20	0.45
13			0.57	0.21	1.09	0.41
14					1.00	0.37
15					0.91	0.34
16					0.83	0.31
17					0.76	0.28
18					0.69	0.26

The program includes the design of a suitable two-wire feeder line for any specific impedance. Input requirements for the feeder design are the impedance desired and the dipole element length to diameter ratio. The output is the required feeder spacing to diameter ratio. The program is valid for antennas in free space and frequencies at VHF and above. At these frequencies the ground effect can be neglected mounting the antennas high enough above the ground. For lower

frequencies this program can be used for a first order estimation.

The Mini-Numerical Electromagnetics Code (MININEC) can be used for the design and analysis of wire antennas. The program is based on the numerical solution of integral equations for the currents used on the structure by an exciting field. MININEC calculates the current distributions, impedances and radiation patterns for wire antennas arbitrary oriented in free space or over perfectly conducting ground.

The program named "Patterns of Long-Wire Antennas" can be used to design long-wire antennas. It calculates the pattern gain functions for long-wire, traveling wave dipole, VEE, and rhombic antennas. The effect of a ground plane on the patterns can be included.

B. Two-port network analysis and matching

The program named "Transmission Lines" calculates the characteristic impedance of twelve different line configurations. The calculation is based on the geometry of the lines and the dielectric constant. In each case the attenuation is neglected. The program can also determine the input impedance for a given line length and load at a specified frequency.

The program "Broadband matching" is suitable for broadband matching network design. For example, the performance of the broadband antenna can be improved through the use of matching network at the antenna feed point. Typical VSWR value for the operating bandwidth is 2:1. Few antennas inherently satisfy this criterion over the entire designed band, thus a broadband matching network has to be added between the antenna feed points and the transmission line.

There exists a great number of procedures for designing a broadband matching network. The procedures are sometimes complicated and may not work in all cases. The procedure given here is a trial and error process which is easier to solve while the impedances are plotted in the Smith chart. The matching network consists of lumped reactances (capacity and inductivity) in a ladder configuration. The proper selection of the elements in the ladder network is based on the user's experience and the load impedance frequencies curve. If the load impedance frequency curve is similar to the parallel resonant circuit the first element has to be serial to the load impedance and vice versa. The network should consist of as few elements as possible to minimize the losses. The efficient broadband matching network has to be built up with the minimal number of elements. As an upper limit, very little improvement has been observed with a matching network with more than five elements.

The network in Fig.1. is used as an example of visualizing the matching process. All impedances are normalized on the characteristic impedance of 50 Ω. The load impedance consists of a parallel resonant circuit with a resonant frequency at 500 MHz. To obtain the satisfactory VSWR of 2:1 we have to add a serial resonant circuit as a matching network. After some iterations the absolute values of the normalized

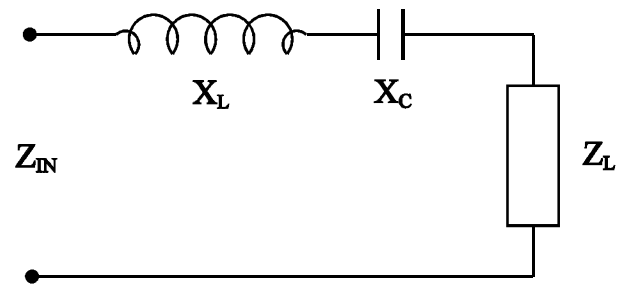


Fig.1. Matching network with serial resonant circuit

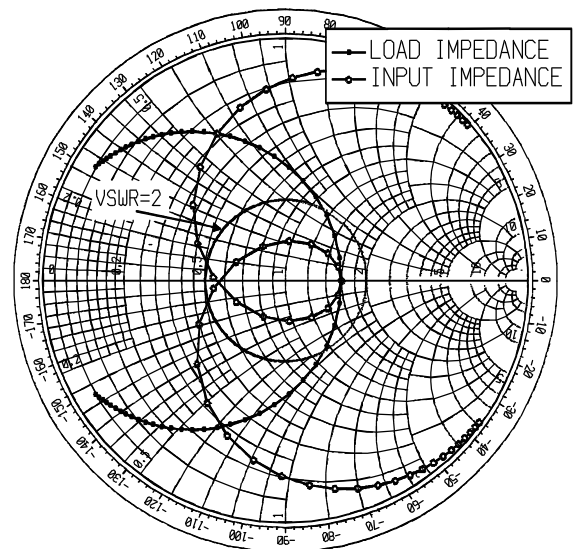


Fig.2. Smith chart representation of load and input impedances for the matching network in Fig.1.

impedances of the matching network were chosen: $X_C / Z_0 = X_L / Z_0 = 14$. The load impedance and the input impedance of the matching network are plotted on the Smith chart (Fig.2.). The frequency increments on the impedance curve are 2 MHz. Taking the maximum value of VSWR 2:1 as a criterion, after matching we obtain the bandwidth of 28 MHz. Adding a parallel resonant circuit at the input of the network in Fig.1. we obtained a new matching network (Fig.2.) with a wider bandwidth. After same iterations to achieve the maximum bandwidth for the value of VSWR 2:1 the following normalized impedances and admittance's were chosen: $X_C/Z_0 = X_L/Z_0 = 16.25$, $B_C/Y_0 = B_L/Y_0 = 12$. The load impedance is the same as in a previous example. From the Smith chart in Fig.4. it is notable that the

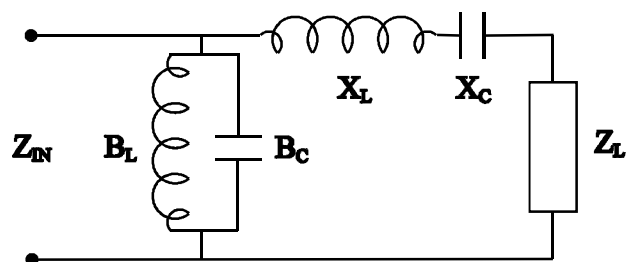


Fig.3. Matching network with one serial and one parallel resonant circuit

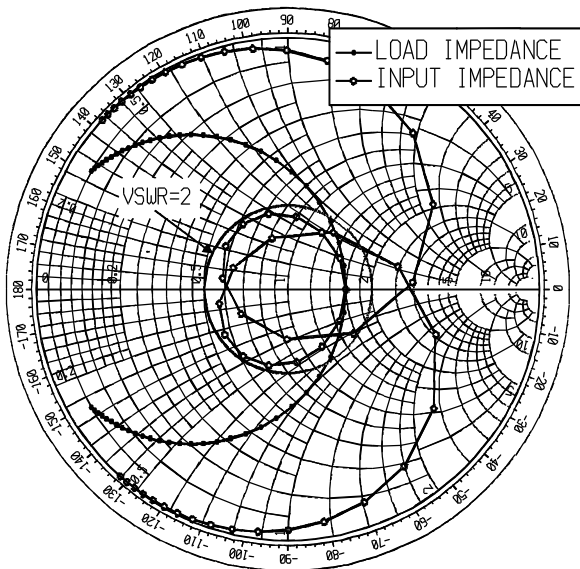


Fig.4.Smith chart representation of load and input impedances for the matching network in Fig.3.

input impedance consists of two loops placed inside the VSWR 2:1 circuit. In this manner the wider bandwidth of 41 MHz is achieved.

The program "Stub Matching" is used for a single stub matching of a load to a lossless transmission line. Commonly, the stub consists of short-circuited or open-circuited transmission lines of lengths shorter of the quarter wavelength. These transmission line sections represent reactances or susceptances in the stub-matching circuits.

C. Intermodulation

The program "Intermodulation Analysis" calculates the intermodulation order on a given frequency produced by a set of transmit frequencies. Two or more collocated transmitters tend to produce an interference signal known as intermodulation interference. The order of the intermodulation relates inversely to the effect of the interference. As the order goes down, the number of intermodulation frequencies goes down but the level of the interference goes up. A capability for finding the lowest order of intermodulation is very useful for evaluation of any frequency plan.

The program "Intermodulation Frequencies" calculates the intermodulation frequencies of a given intermodulation order produced by a maximum of three transmitters. It is important to know these intermodulation frequencies which can cause severe interference problems. Thus, a frequency assignment can be made which will avoid the use of these frequencies for reception. If three transmitting frequencies f_1 , f_2 and f_3 are chosen, the third order intermodulation frequencies are $f = n_1 f_1 + n_2 f_2 + n_3 f_3$, where n_1 , n_2 and n_3 are integers. In the Table II these frequencies are: $f_1 = 451.1$ MHz, $f_2 = 451.5$ MHz and $f_3 = 451.8$ MHz. The intermodulation frequencies appear in two groups concentrated in the vicinity of 450 MHz and 1350 MHz. These frequencies are

approximately the values of fundamental frequencies and the third harmonics of the chosen group of transmitting frequencies.

f in MHz	n_1	n_2	n_3
450.4	2	0	-1
450.7	2	-1	0
450.8	1	1	-1
451.2	0	2	-1
451.4	1	-1	1
451.9	-1	2	0
452.1	0	-1	2
452.2	-1	1	1
452.5	-1	0	2
1353.3	3	0	0
1353.7	2	1	0
1354.0	2	0	1
1354.1	1	2	0
1354.4	1	1	1
1354.5	0	3	0
1354.7	1	0	2
1354.8	0	2	1
1355.1	0	1	2
1355.4	0	0	3

III CONCLUSION

The described tools are verified through many-years application in the teaching process at the Radiocommunications course at the Post Secondary Technical School in Zagreb. Through the use of these programs students get acquainted with the basic parameters and computations in various areas of radiocommunications.

In simulations, the real values from the engineering practice are given as input parameters into the programs. Thus, the students will get accustomed to this values and will easier solve their future tasks as engineers.

In the teaching process, when the laboratory is not available, computer simulations are the only solution for the students to improve their knowledge in solving practical engineering problems. In this manner, the "PC Tools for Radio Communications Engineering" support the teaching process and stimulate the students to creatively apply their knowledge in the network analysis, antenna design and analysis, transmission line analysis, propagation analysis and communication link analysis. In the case when the laboratory exists, these tools can be used for additional insight in the engineering problems by comparing the measured and computed results.

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