

A BROADBAND COMBINED (LINEAR AND LOOP) ANTENNA ABOVE A GROUND PLANE

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INTRODUCTION

Antennas that possess broadband characteristics, high radiation efficiency and low dimensions are important in practical applications, for example in mobile communication systems. Wide bandwidth is fundamental in antennas for transmitting broadband signals, in particular, video signals and signals with high transmission rate. In antenna theory, it is well known that small antennas possess narrow bandwidth and small radiation resistance, i.e. small radiation efficiency [1].

General fundamental limits of the antenna performances with respect to the parameters mentioned above were firstly established by Wheeler [2] and Chu [3]. These authors obtained the identical results about the effect of the dimension reduction on the bandwidth. One of their conclusions is that the minimum radiation factor that any antenna can have is only possible when this antenna radiates the fundamental modes TM_{10} e TE_{10} with equal energy. The fields of these modes are the same that those of the infinitesimal electric and magnetic dipoles, respectively. One can say that a smaller radiation factor leads to a larger bandwidth [3]. Collin [4] in 1964 confirmed the Chu results using field theory to compute the radiating energies. Fante [5] in 1969, generalized the ideas of Collin to an antenna that radiates any spherical mode. In [6], McLean made a verification of these fundamental limits using infinitesimal dipoles, and he suggested a simpler method to obtain the limits. Recent results that confirm these theories can be found in [7]-[9].

Four types of combinations of electric and magnetic dipoles in free space and with single feeding are presented in [10]. The authors showed theoretically that these antennas can possess broadband matching with the bandwidth about 86%. The electric and magnetic dipoles should be combined in such a manner that their moments are orthogonal. The interaction between them (coupling) is stronger for such orientation of the dipoles.

In this work, we present three types of broadband combinations of linear and loop antennas with single feeding placed above a perfect ground plane. These antennas are analyzed by the Method of Moments (MoM) [11] and the antenna's dimensions are optimized to obtain a large matching bandwidth. We calculate the reflection coefficient, gain, and radiation diagrams of these antennas.

DESCRIPTION OF THE ANTENNAS

The geometries of the analyzed antennas are shown in Fig. 1. In all these configurations, the source is put in the middle of the electric linear antenna (dipole) and the loops are near this dipole with only electromagnetic coupling between them. In this figure, square loops are shown. To comparison, the configurations with circular loops are also analyzed. In these cases, the diameter of the circular loop is equal to the side of the corresponding square loop.

In all of these antennas, L_d is the length of the electric dipole and L_e is the side of a square loop (or diameter in the case of circular loop). In the first case shown in Fig. 1(a), we use one electric dipole and one loop. These two elements are centralized with respect to the origin of the axes x and y , but they lie in different planes along the z -axis. The first element is in the plane $z=h_d$ and the second one in the plane $z=h_e$. Fig. 1(b) also shows a combination of one electric dipole and one loop for different position of the loop. The distance between the loop and the dipole is d_l . In Fig. 1(c), there is one electric dipole and two loops. These three elements are centralized with respect to the axis x and y , but in different planes along the z -axis. The electric dipole is in the plane $z=h_d$ and the loops are in the planes $z=h_{e1}$ and $z=h_{e2}$.

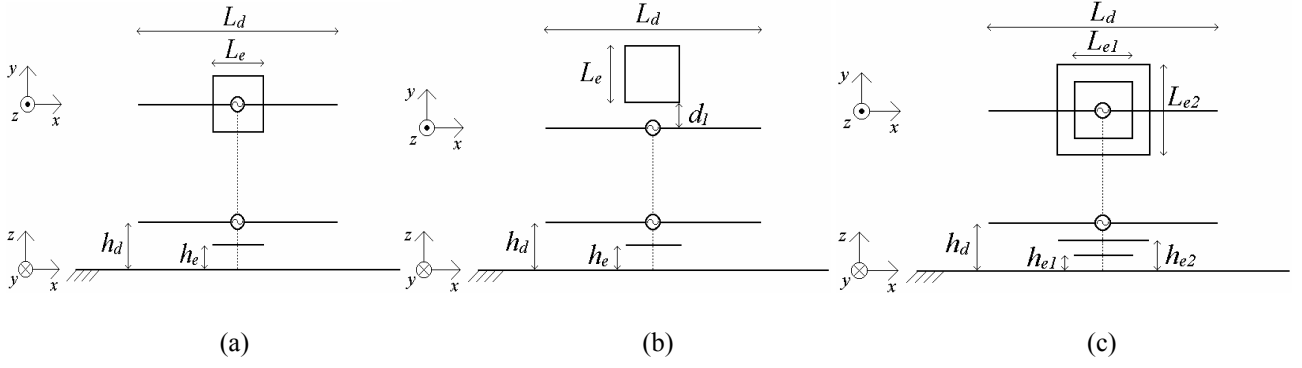


Fig. 1. Geometries of the three types of combination of linear and loop elements above a ground plane. (a) Case 1. (b) Case 2. (c) Case 3.

NUMERICAL RESULTS

The numerical analysis of these antennas is made by using MoM codes developed by Matlab 6. In this code, we use rectangular pulse for basis functions and the Dirac's functions for test functions. We use 15 segments of discretization for the horizontal electric dipole, 16 for the circular loops and 5 in each side of the square loops.

Reflection Coefficient and Gain

For the three antennas described above, we made many simulations with different values of the parameters L_e , L_{e1} , L_{e2} , h_d , h_{e1} , h_{e2} and d_l , and the two types of loop (circular and square). In all of these simulations we fixed the height of the electric dipole in $h_d=0.3L_d$ and the radius of the transversal section of the conductors is $a=L_d/200$. The antennas which had better results with respect to their bandwidths are presented in Table 1. The values of the parameters in this table are normalized to the length of the electric dipole L_d .

TABLE I DIMENSIONS OF THE ANTENNAS WITH LARGEST MATCHING BANDWIDTH

	Case 1		Case 2		Case 3	
	Circular	Square	Circular	Square	Circular	Square
L_e	0.25	0.25	0.30	0.25	-	-
L_{e1}	-	-	-	-	0.25	0.20
L_{e2}	-	-	-	-	0.25	0.25
h_e	0.35	0.35	0.27	0.27	-	-
h_{e1}	-	-	-	-	0.24	0.32
h_{e2}	-	-	-	-	0.33	0.33
d_l	-	-	0.03	0.03	-	-

The numerical results of the input matching ($\Gamma=|(Z_{in}-Z_0)/(Z_{in}+Z_0)|$, where Z_0 is the transmission line impedance and Z_{in} is the input impedance) and gain are shown in Fig. 2. The gain is calculated for the direction normal to the ground plane (+z). This gain is for the x-polarized wave. The gain of these antennas in direction y is null. In this figure, the reflection coefficient of the isolated horizontal electric dipole is also shown for comparison. The isolated electric dipole has the length L_d and the height $h_d=0.3L_d$. The bandwidth of this dipole is 5% (with $Z_0=30$ Ohms).

Table II shows the bandwidth of these optimized antennas ($B=200 \times (f_s - f_i) / (f_s + f_i)$, where f_s is the superior frequency and f_i is the inferior frequency with respect to the level of -10dB of the reflection coefficient). In this table, we present also the central normalized length L_d/λ_c , where λ_c is the wavelength in the central frequency of the band $f_c=(f_s+f_i)/2$, and the values of the characteristic line impedance Z_0 used for calculations.

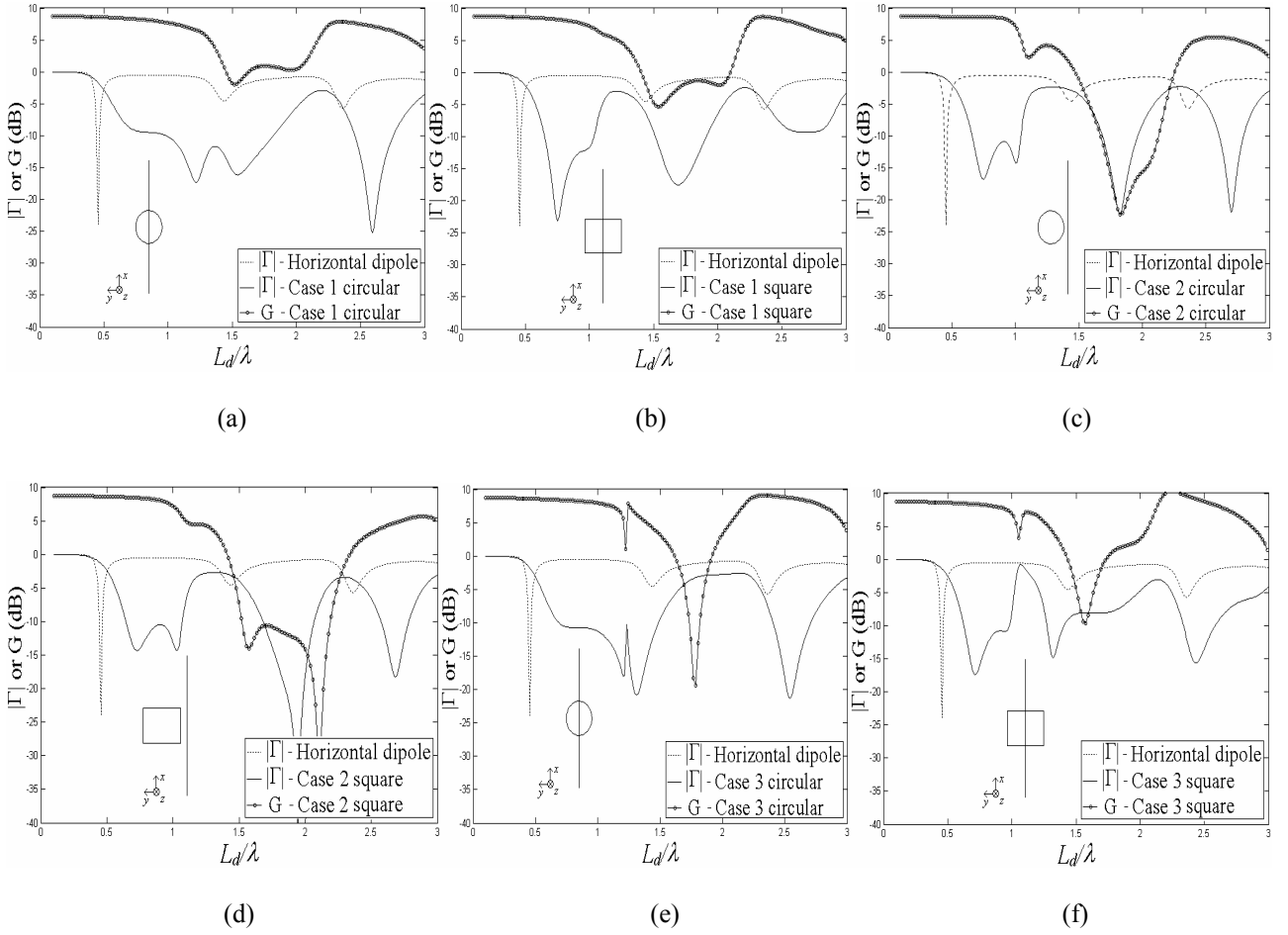


Fig. 2. Input impedance and gain of the optimized antennas. (a) Case 1 circular. (b) Case 1 square. (c) Case 2 circular. (d) Case 2 square. (e) Case 3 circular. (f) Case 3 square.

TABLE II BANDWIDTH B OF THE OPTIMIZED ANTENNAS

	Loop	B (%)	Z_0 (Ohms)	L_d/λ_c
Case 1	Circular	60	350	1.41
Case 1	Square	45	500	0.85
Case 2	Circular	45	550	0.86
Case 2	Square	49	450	0.87
Case 3	Circular	73	320	1.01
Case 3	Square	43	400	0.81

Radiation Diagrams

The radiation diagrams of these optimized antennas (Table 1) are shown in Fig. 3, 4, 5, 6, 7 and 8. The frequencies L_d/λ_c at which these diagrams were calculated, are given of in Table 2. In these figures, θ and ϕ are the usual spherical coordinates. These graphics correspond to the x polarization. The component of the y polarization is null.

The radiation diagram of the Case 1 (circular loop) on the plane xz (Fig. 3(a)) has side lobes. This is because the value of the central wavelength ($\lambda_c=1.41$) and the radiation diagram of a conventional electric dipole in this frequency has side lobes [1]. The radiation diagrams of the other antennas do not have side lobes. We also observe from Fig. 5(b) and Fig. 6(b) that the diagrams for these cases are asymmetric. This asymmetry exists in the plane yz . In the other cases, the diagrams possess symmetry in both the planes xz and yz . These results are in agreement with the geometries of the antennas shown in Fig. 1.

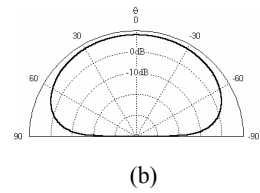
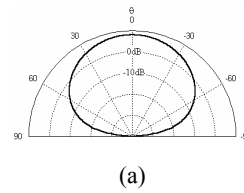
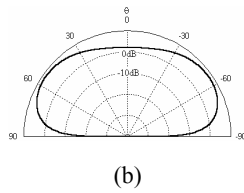
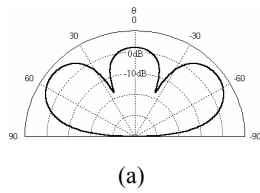


Fig. 3. Diagrams of the Case 1 circular. (a) Plane xz . (b) Plane yz .

Fig. 4. Diagrams of the Case 1 square. (a) Plane xz . (b) Plane yz .

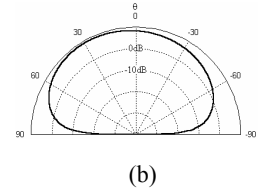
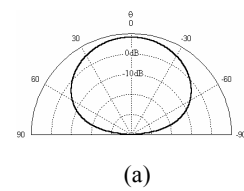
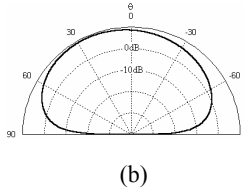
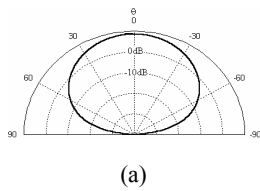


Fig. 5. Diagrams of the Case 2 circular. (a) Plane xz . (b) Plane yz .

Fig. 6. Diagrams of the Case 2 square. (a) Plane xz . (b) Plane yz .

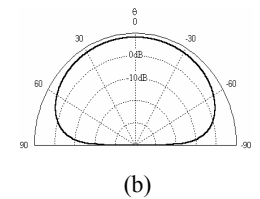
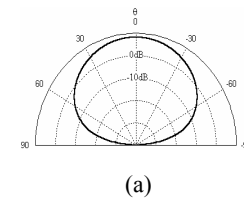
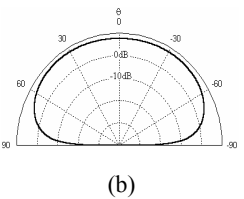
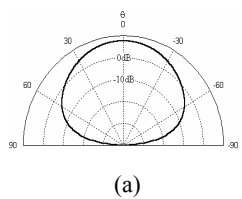


Fig. 7. Diagrams of the Case 3 circular. (a) Plane xz . (b) Plane yz .

Fig. 8. Diagrams of the Case 3 square. (a) Plane xz . (b) Plane yz .

CONCLUSIONS

This work presents some preliminary results of optimization of combined antennas consisting of linear antenna and loops placed above an infinite ground plane. The obtained results show the input matching bandwidth up to 73% for the fixed height of $h_d=0.3L_d$. We observed that the bandwidth for smaller height h_d is diminished. In all the simulations, the obtained bandwidth is in the range $20\%<B<40\%$. The results show also that these types of antennas possess linear polarization in the direction normal to the ground plane and the values of the gain in this direction are usually larger than 5 dB in the range of matching $|\Gamma|<-10\text{dB}$.

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