Recent Progress in Broadband Antennas

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Abstract

Seven antennas with broadband radiation characteristics are presented: an equiangular spiral antenna with a shallow conducting cavity, a curl antenna above an EBG reflector, a fan-shaped antenna, a cross fan-shaped antenna, a BOR-PARP antenna, a trapezoidal log-periodic antenna, and a log-periodic dipole array. Special attention is paid to the input impedance of these antennas.

1. Introduction

This paper presents recent progress in broadband antennas. Seven antennas are discussed in subsections 2-A through 2-E.

The antenna structure in subsection 2-A consists of an equiangular spiral element and a cavity for generating a circularly polarized unidirectional beam. A technique for restoring the broadband input impedance characteristic of the spiral is discussed [1]. Subsection 2-B describes a curl element backed by an EBG reflector, where the height from the EBG reflector surface to the curl is extremely small (0.06 wavelength). An impedance matching technique to a 50-ohm transmission line is presented [2].

The antenna in subsection 2-C, called a fan-shaped antenna, radiates a linearly polarized wave [3]. The fan-shaped antenna has a card-type structure. This subsection also presents a compound of two fan-shaped elements backed by a ground plane, called a cross fan-shaped antenna [4]. This cross fan-shaped antenna has a vertical structure and is designed to radiate an omni-directional beam in the direction normal to the antenna axis.

The BOR-PARP antenna in subsection 2-D is also designed to have an omni-directional beam [5]. The antenna is constructed from a conducting body of revolution surrounded by a parasitic conducting ring with conducting pins. The pins are short-circuited to the ground plane. Subsection 2-E presents a trapezoidal log-periodic antenna (Trpz-LPA) and a log-periodic dipole array (LPDA). The input impedances of these antennas have been considered experimentally [6][7], however, it has not been obtained theoretically while taking into account the finite antenna structure. Therefore, this subsection reveals the theoretical input impedance for both the Trpz-LPA and the LPDA. Furthermore, the input impedance when one arm of the Trpz-LPA is repositioned to give the antenna a line-symmetric structure is discussed. Finally, the input impedance for an LPDA with transposed excitation [8][9] is compared with that for an LPDA with non-transposed excitation.

2. Discussion

A. Equiangular spiral antenna backed by a cavity with absorbing strips

The antenna element in this subsection is an equiangular spiral with an outer diameter of 113 mm, backed by a circular conducting cavity with a diameter of D_{cav} = 120 mm, as shown in Fig. 1(a). It is emphasized that the cavity depth H_{cav} is chosen to be very small: H_{cav} = 7 mm, which is approximately 0.047 wavelength at 2 GHz. The solid line in Fig. 1(c) shows the input impedance for this cavity-backed spiral. It is found that, as the frequency decreases, the input impedance varies remarkably. One technique for restoring the inherently broadband input impedance of the spiral is to attach absorbing strips (ABSs) to the inside of the cavity, as shown in Fig. 1(b). One important parameter for specifying the ABSs is the arc angle ϕ_{ABS}, which is measured from the arm end. The black and white dots in Fig. 1(c) show the input impedance for ϕ_{ABS} = 90 degrees and 180 degrees, respectively. Note that when ϕ_{ABS} = 180 degrees, two ABSs are connected to form a ring ABS, which completely covers the vertical wall of the cavity. As seen from the black and white dots in the figure, the input impedance for each ϕ_{ABS} exhibits a broadband characteristic, where the resistive component R_{in} is approximately 150 ohms.

B. Curl antenna above an EBG reflector

A curl antenna is a spiral radiation element made of a single conducting arm, for which the outer circumference is usually chosen to be greater than one wavelength, but less than two wavelengths. Conventionally, the curl is backed by a conducting plane (PEC plane) to form a unidirectional beam of circular polarization [10]. It has been found that, as the antenna height (the distance between the curl plane and the PEC plane) is decreased, the curl loses its inherent broadband input impedance characteristic. Note that this issue has been solved by replacing the PEC reflector with an EBG reflector [11]; however, a problem still exists in that the value of the input impedance is not suitable for matching to a 50-ohm transmission line. In this regard, this subsection is devoted to improving the impedance matching of the antenna. Fig. 2(a) shows a simple matching technique, where the width of the strip arm is changed. This matching section leads to a broadband VSWR characteristic, as shown by the solid line in Fig. 2(b), where a bandwidth of 50% is obtained. For reference, the VSWR for a curl without the matching section is also shown in the same figure, with a dotted line.

C. Fan-shaped and cross fan-shaped antennas

The increasing demand for mobile communications has been accelerating development of broadband antennas. This subsection discusses a new broadband antenna, called a fan-shaped antenna [3][12]. The fan-shaped antenna has a flat structure (card-type structure), as shown in the inset of Fig. 3, where both the top radiation element (fan-shaped element) and the ground plate lie in the same plane. The fan-shaped element has a very small area (approximately 1 cm × 1 cm), where the lower edge (from points Q to P) is specified by an exponential function. Fig. 3 shows the frequency response of the VSWR. It is found that the fan-shaped antenna operates with a VSWR of less than 2 from 3 GHz to more than 10 GHz. Note that the card-type structure facilitates the use of the fan-shaped antenna in PC card devices for personal computers or inside mobile phone handsets.

Fig. 4 shows an application of the fan-shaped structure as a base station antenna, where two fan-shaped elements intersect at a right angle above a ground plane [4]. This antenna, called a cross fan-shaped antenna, is designed to radiate a linearly polarized beam omni-directionally around the z-axis. As seen from Fig. 4, the cross fan-shaped antenna exhibits a broadband VSWR characteristic similar to that of the card-type fan-shaped antenna.

D. BOR-PARP antenna

The BOR-PARP antenna is designed to radiate an omni-directional, linearly polarized beam over a broad frequency range, the same type of beam as for the cross fan-shaped antenna [4]. The main part of this antenna is a conducting *b*ody *o*f *r*evolution (BOR). This BOR is surrounded by a conducting *pa*rasitic *r*ing with conducting *p*ins (PARP). The generating line of the BOR is defined by an exponential function. By optimizing the spacing between the BOR and PARP, a broadband VSWR characteristic is obtained, as shown in Fig. 5. The bandwidth for a VSWR=2 criterion is approximately 1: 7 from 2.17 GHz to 15.27 GHz. Note that the antenna height at the lowest operating frequency 2.17 GHz is extremely small: approximately 0.07 wavelength.

E. Antennas with log-periodic shape

A toothed log-periodic antenna T-LPA [6] is a truncated version of a self-complementary antenna [8]. Fig. 6(a) shows a modified T-LPA, which is called a trapezoidal log-periodic antenna (Trpz-LPA), where the two arms are symmetric with respect to the feed point (point-symmetric structure). Up to now, the input impedance of the Trpz-LPA has not been theoretically calculated while taking its finite structure into account. Fig. 6(b) shows the analysis results of the input impedance for a finite Trpz-LPA. Note that the analysis is performed using the finite-difference time-domain method (FDTDM). It is found that, as the frequency changes, the input impedance exhibits a small wave-like variation around a value of 60π ohms. It can be said that the Trpz-LPA has a broadband input impedance. However, this broadband characteristic disappears if one arm of the Trpz-LPA is repositioned so that the antenna is symmetric with respect to the x-axis (line-symmetric structure), as shown in Fig. 6(c). This is illustrated in Fig. 6(d).

Fig. 7(a) shows a log-periodic dipole array (LPDA), which is a derivative of the log-periodic complementary antenna. The LPDA has transposed excitation [8][9]. Fig. 7(b) shows the frequency response of the input impedance, where all dipole radii are chosen to be the same. It is clear from the figure that the LPDA has a relatively constant input impedance over a frequency range of 250 MHz to 400 MHz. Note that, if the dipoles have non-transposed excitation, as shown in Fig. 7(c), the broadband input impedance characteristic is lost, as shown in Fig. 7(d).

3. CONCLUSIONS

The following conclusions are obtained for the seven antennas. (1) For an equiangular spiral antenna backed by a cavity, the antenna's broadband radiation characteristics are restored by attaching absorbing strips to the cavity. It is not necessary for the vertical cavity wall to be entirely covered to obtain this result. (2) A curl antenna above an EBG has a 50% VSWR bandwidth when a matching section is introduced by changing the width of the arm conductor. (3) A fan-shaped antenna operates over a broad frequency band from 3 GHz to more than 10 GHz. (4) A cross fan-shaped antenna radiates a linearly polarized wave in the direction normal to the antenna axis, making it a candidate for use as a base station antenna. The VSWR is less than 2 above 2.2 GHz. (5) The BOR-PARP antenna radiates a linearly polarized wave omni-directionally. The VSWR bandwidth is approximately 1: 7 from 2.17 GHz to 15.27 GHz. The antenna height is extremely small at the lower edge of the band: approximately 0.07 wavelength. (6) A trapezoidal log-periodic antenna, of which the two arms are symmetric with respect to the feed point (point symmetry), exhibits a broadband input impedance. However, if one of the two arms is positioned to make the antenna line-symmetric, the broadband input impedance characteristic disappears. (7) A log-periodic dipole array with transposed excitation exhibits a broadband input impedance characteristic. However, if non-transposed excitation is used, the broadband characteristic of the input impedance is lost.

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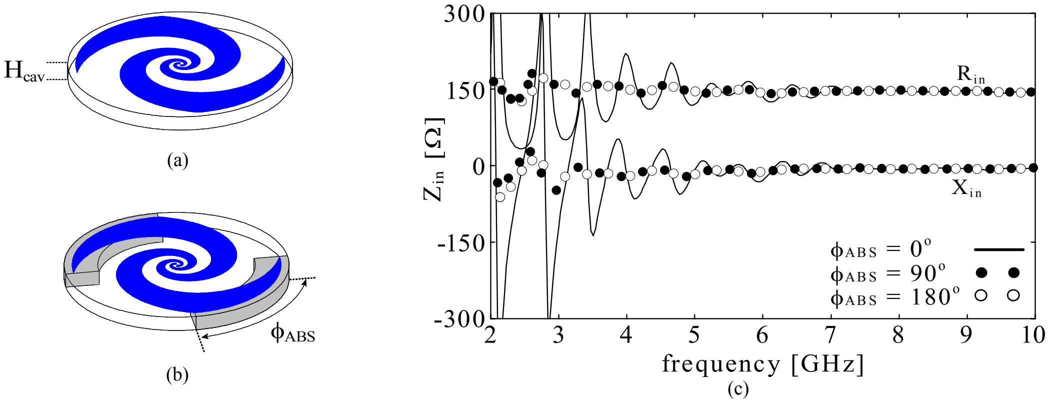

Fig. 1: Equiangular spiral antenna backed by a cavity

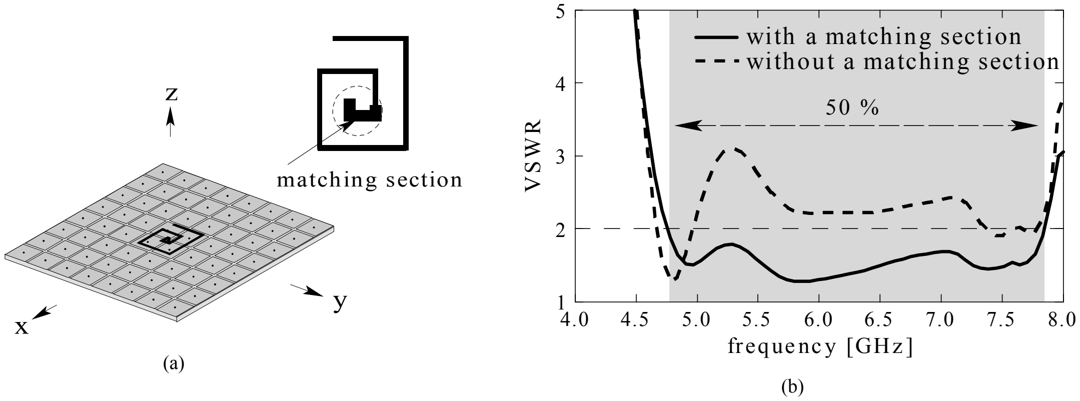

Fig. 2: Curl antenna backed by an EBG reflector

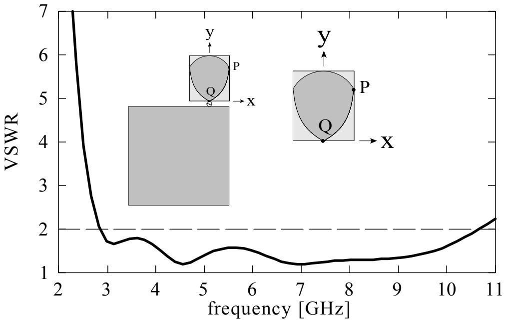

Fig. 3: Fan-shaped antenna

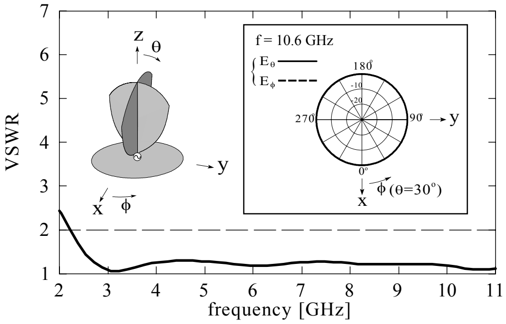

Fig. 4: Cross fan-shaped antenna

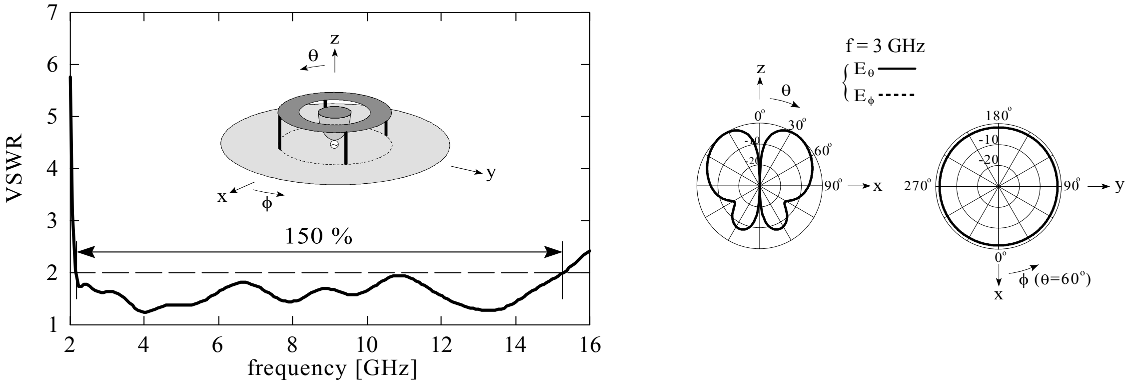

Fig. 5: BOR-PARP antenna

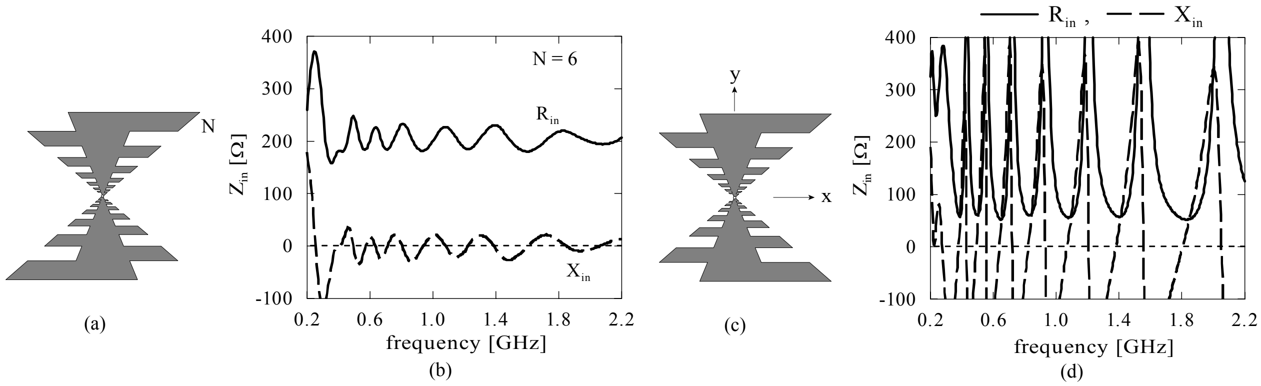

Fig. 6: Trapezoidal log-periodic antenna

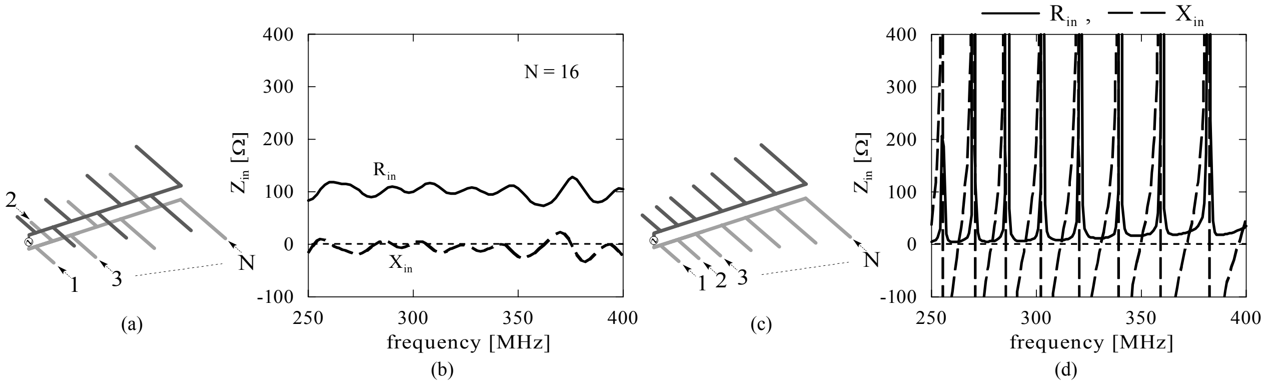

Fig. 7: Log-periodic dipole array