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LOW-PROFILE SPIRAL AND CURL ANTENNAS

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1. Introduction

A spiral antenna has been investigated in the presence of a conducting plane reflector, where the antenna height above the reflector is conventionally chosen to be one-quarter wavelength [1]. This antenna height has been reduced using several techniques: resistive loading [2], open-circuited loading [3], and EBG loading [4]. On the other hand, without any loading, a reflector-backed spiral-like antenna called a curl antenna has an antenna height of less than one-quarter wavelength [5].

The purpose of this paper is to reduce the antenna height of a reflector-backed spiral antenna without any loading. The configuration parameters are appropriately selected so that the antenna radiates a circularly polarized (CP) wave. It is numerically found that, as the antenna height is reduced, the spiral configuration approaches to that of a conventional curl antenna. The present technique without any loading is also applied to the curl antenna and its radiation characteristics are investigated.

2. Low-profile spiral antenna

Fig. 1 shows a two-arm spiral antenna located at height h above a conducting plane reflector. The spiral outer circumference and adjacent wire distance are designated as C and d, respectively. The antenna is fed from the center of a straight wire of length L_f.

Fig. 2 shows the configuration parameters (C, d, L_f) as a function of height h. These parameters are optimized such that the antenna radiates a CP wave with an axial ratio of less than 0.1 dB. It should be emphasized that the length L_f of the straight wire is an important parameter to be appropriately selected for the CP radiation. In other words, the spiral antenna with $h < 0.25\lambda_0$ cannot radiate a CP wave without the straight wire of proper length, where λ_0 is the free-space wavelength. As can be seen from the figure, the distance d monotonously decreases and the circumference C converges to $1\lambda_0$ with decrease in h. The configuration parameters at $h = 0.15\lambda_0$, for example, are (C, d, L_f) = ($1.20\lambda_0$, $0.02\lambda_0$, $0.20\lambda_0$).

The frequency bandwidth for a 3-dB axial-ratio criterion against h is presented in Fig. 3. The bandwidth decreases as the antenna height h is reduced. The bandwidth of 24% at $h = 0.25\lambda_0$ decreases to 8% at $h = 0.15\lambda_0$. Fig. 4 shows the input impedance $Z_{in} = R_{in} + j X_{in}$ versus h. It is observed that the input impedance is almost purely resistive even when the height h is reduced. The resistance R_{in} becomes higher as h decreases.

So far, a low profile spiral antenna has been analyzed using a technique of optimizing the configuration parameters for the CP radiation, and the radiation characteristics are discussed. This technique is further applied to a curl antenna in the next section.

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3. Low-profile curl antenna

Fig. 5 illustrates a curl antenna backed by a ground plane. The antenna is composed of vertical wire *a*-*a*' and horizontal wire *a*-*b*-*t*. The horizontal wire consists of straight wire *a*-*b* of length $L_f/2$ and curl wire *b*-*t* of outer circumference C and adjacent wire distance $2d$. (The definitions of $L_f/2$ and $2d$ are based on those for the two-arm spiral antenna shown in Fig. 1. Note that the curl antenna has a single-arm configuration.) The vertical wire length (antenna height) is designated as h. The antenna is fed by a coaxial line from bottom point *a*' of the vertical wire.

Preliminary calculation shows that a conventional curl antenna having $h = 0.15\lambda_0$ radiates a CP wave with an axial ratio of less than 0.1 dB, when the parameters are $(C, d, L_f) = (1.19\lambda_0, 0.02\lambda_0, 0.22\lambda_0)$. These parameters are found to be almost the same as those of the previous spiral antenna at $h = 0.15\lambda_0$. Therefore, it can be said that the conventional curl antenna may be regarded as the low profile spiral antenna whose configuration parameters are optimized for the CP radiation.

Now, the antenna height of the curl antenna is reduced, as in the previous section. Fig. 6 shows the changes in parameters (C, d, L_f) with reduction in h, where the parameters are determined under the condition that the antenna radiates a CP wave with an axial ratio of less than 0.1 dB. It is seen that, as h is reduced to $0.10\lambda_0$, C and L_f remain almost unchanged, while d monotonously decreases. This monotonous decrease in d is also observed for the spiral antenna (see Fig. 2).

Fig. 7 shows the frequency bandwidth for a 3-dB axial-ratio criterion as a function of h. The bandwidth of 8% at $h = 0.15\lambda_0$ decreases to 3% at $h = 0.10\lambda_0$. It should be noted that an antenna height of $h = 0.10\lambda_0$ cannot be realized for the previous spiral antenna, since (the monotonously decreased) d is too small for the spiral antenna to be constructed. By virtue of the single-arm configuration, the curl antenna can be realized with lower antenna height than that for the two-arm spiral antenna.

Fig. 8 depicts the input impedance $Z_{in} = R_{in} + j X_{in}$ with reduced height h, where R_{in} gradually decreases, as opposed to the case for the spiral antenna shown in Fig. 4. This is attributed to the fact that the curl antenna is excited with an unbalanced feed by a coaxial line, while the spiral antenna is exited with a balanced feed.

4. Conclusions

The antenna height of a reflector-backed spiral antenna has been reduced without any loading. The configuration parameters are optimized such that the antenna radiates a CP wave with an axial ratio of less than 0.1 dB. It is numerically found that the antenna height can be reduced to $0.15\lambda_0$, where the configuration parameters are found to be close to those of a conventional curl antenna. The curl antenna is also analyzed with reduced antenna height. The analyses show that the frequency bandwidth for a 3-dB axial-ratio criterion is 3% for an antenna height of $0.10\lambda_0$.

References

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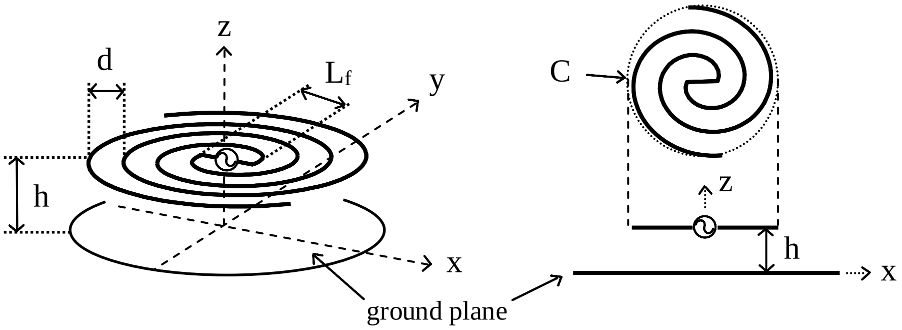

Fig. 1 Spiral antenna

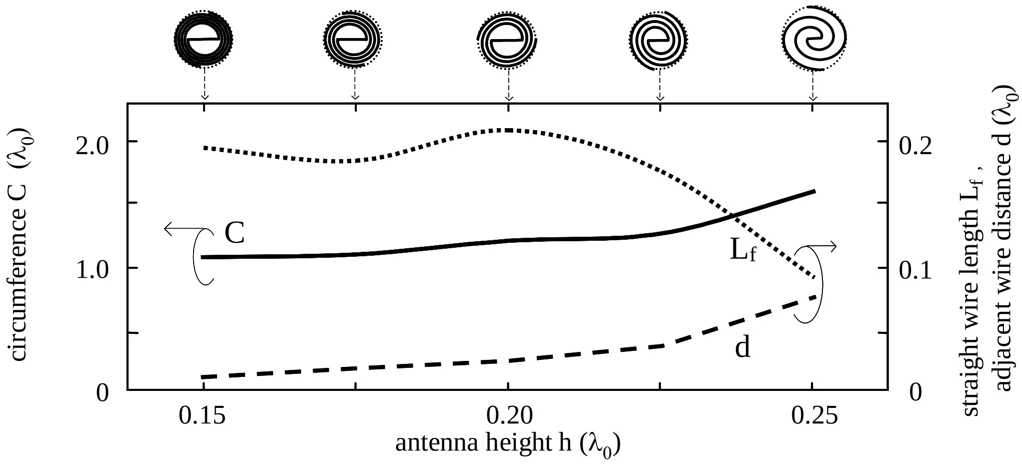

Fig. 2 Configuration parameters vs. height h

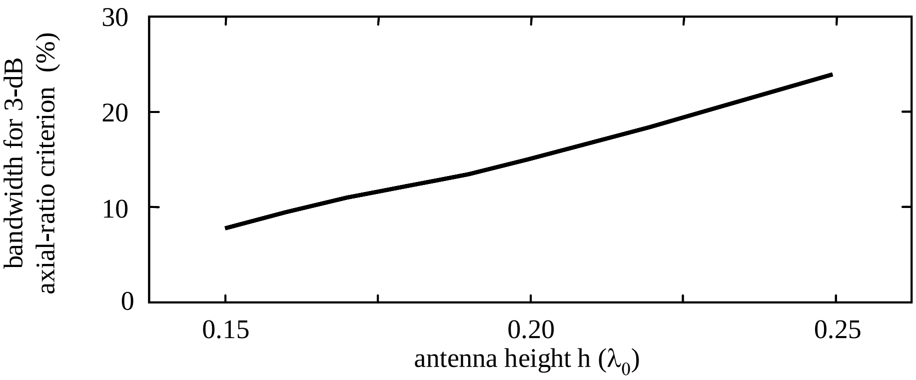

Fig. 3 Axial-ratio frequency bandwidth vs. height h

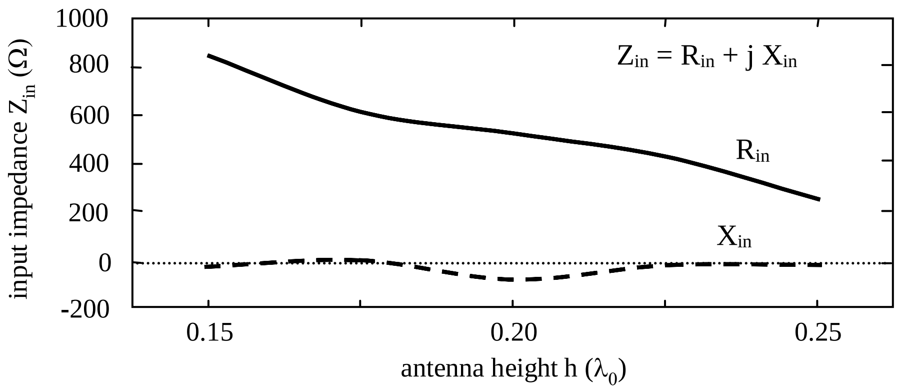

Fig. 4 Input impedance vs. height h

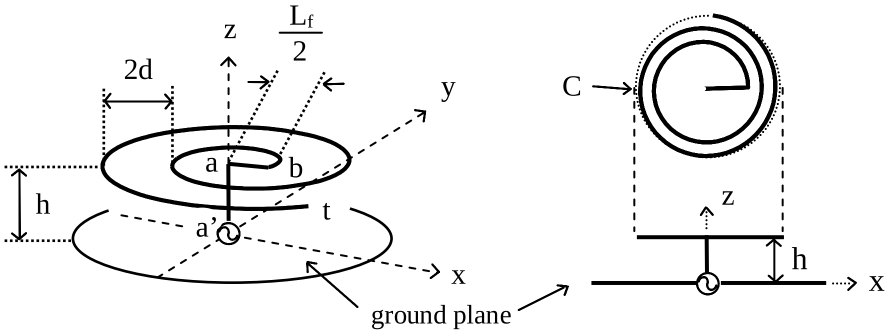

Fig. 5 Curl antenna

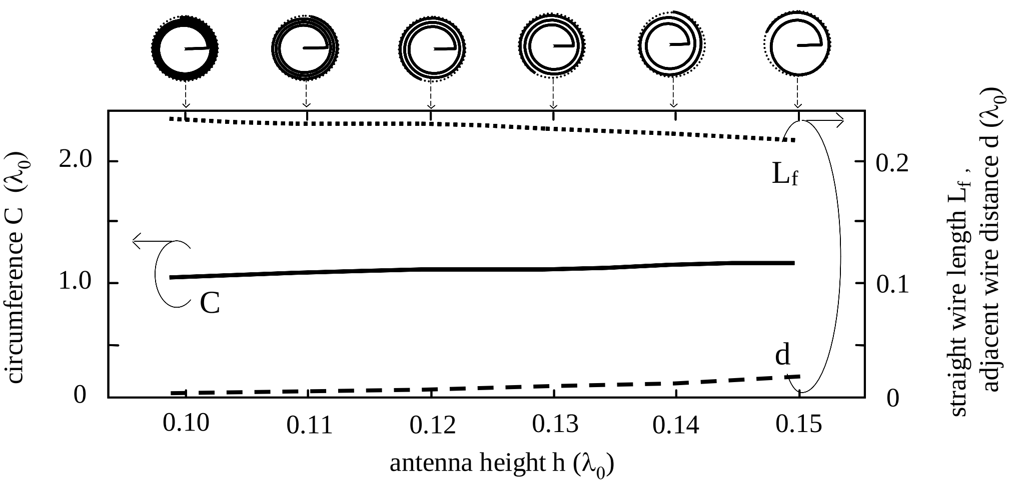

Fig. 6 Configuration parameters vs. height h

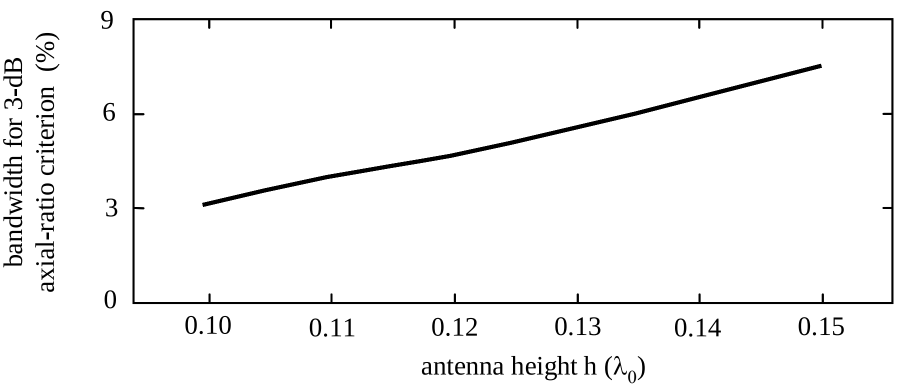

Fig. 7 Axial-ratio frequency bandwidth vs. height h

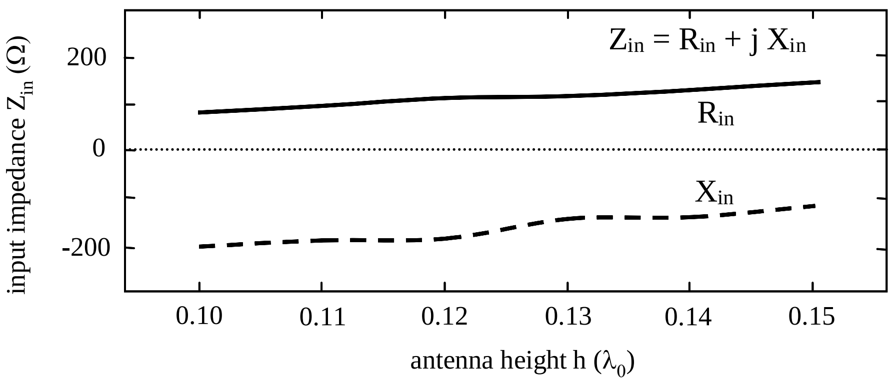

Fig. 8 Input impedance vs. height h