A LOW-PROFILE HELIX RADIATING A CIRCULARLY POLARIZED WAVE

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Introduction

The radiation behavior of a helical antenna with a finite ground plane has been analyzed by using numerical techniques [1]. The numerical results show that the helix whose circumference is in the order of one wavelength inherently radiates in the back-fire mode, and that the back-fire mode is changed into the forward-fire mode by the ground plane. It should be noted that the helices which have so far been analyzed have pitch angles of more than 10 degrees.

This paper refers to helices with low pitch angles of less than 7 degrees. A low pitch-helix has been recognized as an ineffective radiating element for a circularly polarized wave (C.P.W.) and has never been used in practice. The numerical results presented in this paper, however, lead to new aspects of a low pitch-helix as an effective radiating element.

Configuration

Fig.1 shows a helix mounted on a ground plane of infinite extent. The inner conductor of a coaxial line used for the feed is bent at a height h above the ground plane and extended to the starting point of the helix proper. The bending angle is 90 degrees. The configuration parameters are designated as follows: pitch angle α, helical circumference c, wire radius ρ, and number of helical turns n. The helical pitch angle ranges from 4 to 7 degrees, while the helical circumference, the wire radius, and the bending height are fixed to be $c=1\lambda$, $\rho=0.02\lambda$, and $h=0.05\lambda$, respectively, where λ is the free-space wavelength.

Numerical method

The condition that a perfectly conducting ground plane under the helix is of infinite extent can lead to a numerical model of a bidirectional helix, due to the image effect of the real helical arm. In order to obtain the current distribution on the helical arm, the moment method is applied to a Pocklington type integral equation for an arbitrary wire configuration [2]. The application of the moment method requires subdivisions of more than 16 segments per helical turn, taking account of the convergence of the numerical results. The obtained current distribution is used to calculate the radiation characteristics.

Discussion

Fig.2 shows the calculated current distribution and radiation patterns of a 10-turn long helix with a low pitch angle of 4 degrees, at a test frequency of 12 GHz ($\lambda=25$ mm). The axial ratio on the Z-axis is poor, a value of 4.5 dB, confirming the criticism that a low-pitch helix is not an effective antenna for radiating a C.P.W. The deterioration in the axial ratio is also found for other low pitch angles, as shown in Fig.3.

Recent theoretical investigations [3][4] have shown, however, that there are two ways to overcome the axial ratio deterioration: (1) tapering the helical turns near the open end, in order to reduce the reflected current from the arm end, and (2) using only the first few helical turns where the decaying current travels from the feed point to the first minimum point. This paper adopts the latter technique, which allows the realization of a low-profile helix.

Unfortunately, the minimum point in the current distribution is not clearly defined for low-pitch helices. Therefore, calculations are made for helices of up to 3 turns. Fig.4 shows the calculated results of axial ratio on the Z-axis as a function of the helical turns. The upper horizontal axis is the axial length for a 4-degree pitch angle helix, expressed in terms of the free-space wavelength. It is found that excellent axial ratios are obtained, even though the axial lengths are extremely short, i.e., the helix has a low profile.

A 4-degree pitch, 2-turn helix has an axial ratio of 0.5dB with an axial length of 0.19 wavelengths. Fig.5 shows the current distribution and radiation patterns for this case. The phase progression of the current distribution changes linearly with a phase velocity being approximately equal to that in free space. The half-power beamwidth of the radiation pattern is about 70 degrees in both principal planes.

Further investigation confirms that the low-profile helices have wide-band frequency responses for both the axial ratio and antenna gain. Fig.6 is an example of the frequency response for the above-mentioned 2-turn helix of 4-degree pitch angle. The antenna gain is calculated to be approximately 9dB, which is comparable to a gain realized by a conventional long helix for an axial length of 0.9 wavelengths, a circumference of one wavelength, and a pitch angle of 12.5 degrees. The bandwidth for an axial ratio of less than 3dB is calculated to be 12% for this 2-turn helix.

Application of Low-Profile Helix

A low-profile helix can be used as an array element for a flat type antenna, as shown in Fig.7. The feed wire of each element is inserted into a radial waveguide[5] through a small hole and excited by a traveling wave flowing in the *TEM*-mode between the two parallel plates of the waveguide. The physical rotation of each element around its feed wire can satisfy the phase conditions required for forming a specific beam [6].

Fig.8 shows the measured radiation pattern after phase adjustment to form a main beam in the direction of the Z-axis. The antenna aperture efficiency of a helical array consisting of 152 elements on a 30cm-diameter radial waveguide shows a value of more than 70% at 12GHz.

Conclusions

The combination of low pitch and a small number of turns allows one to realize a low-profile helix as a radiating element of circular polarization. It is revealed that the low-profile helix has a wide-band frequency response. A 2-turn helix of 4-degree pitch angle shows a bandwidth of 12% for a 3dB axial-ratio criterion. The feasibility of a high efficiency flat antenna consisting of low-profile helices is also demonstrated for a 12 GHz operating frequency.

References

[1] H.Nakano, J.Yamauchi, and H.Mimaki, "Backfire radiation from a monofilar helix with a small ground plane", *IEEE Trans. AP*. Vol.36, pp.1359-1364, 1988.

[2] H.Nakano, Helical and spiral antennas, Res. Studies Press, Wiley, 1987.

[3] H.Nakano, Y.Samada, and J.Yamauchi, "Axial mode helical antennas", *IEEE Trans. AP*. Vol.34, pp.1143-1148, 1986.

[4] H.Nakano, N.Asaka, and J.Yamauchi, "Radiation characteristics of short helical antenna and its mutual coupling", *Electron. Lett.*, Vol.20, pp.202-204, 1984.

[5] M.Ando, K.Sakurai, N.Goto, K. Arimura, and Y.Ito, "A radial line slot antenna for 12 GHz satellite TV reception", *IEEE Trans. AP*. Vol.33, pp.1347-1353, 1985.

[6] H.Nakano, N.Asaka and J.Yamauchi, "Short helical antenna array fed from a waveguide", *IEEE Trans. AP*. Vol.32, pp.836-840, 1984.

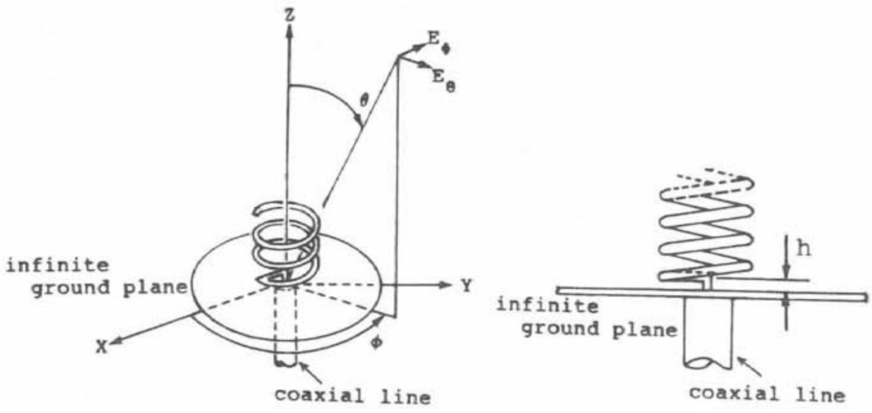


Fig.1 Configuration.

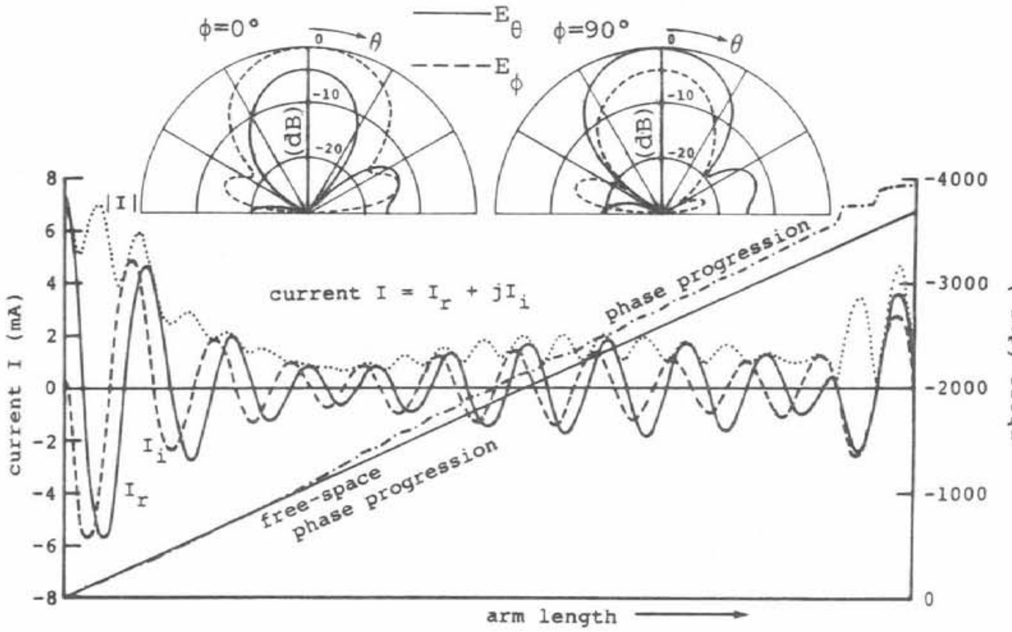


Fig.2 Current distribution and radiation pattern (n=10).

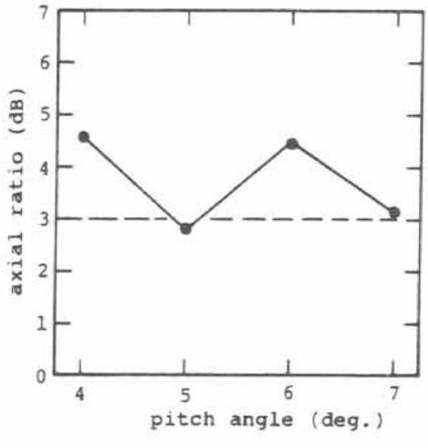


Fig.3 Axial ratio (n=10).

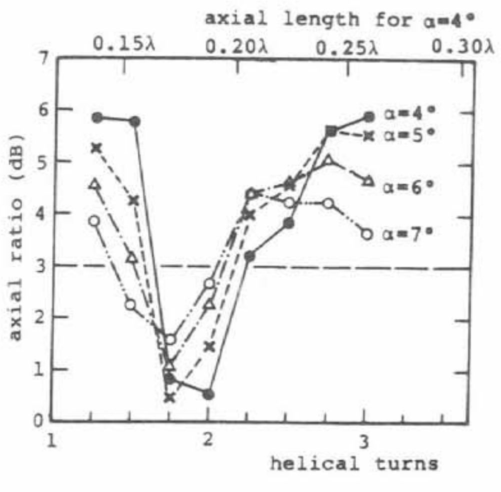


Fig.4 Axial ratio vs. helical turns.

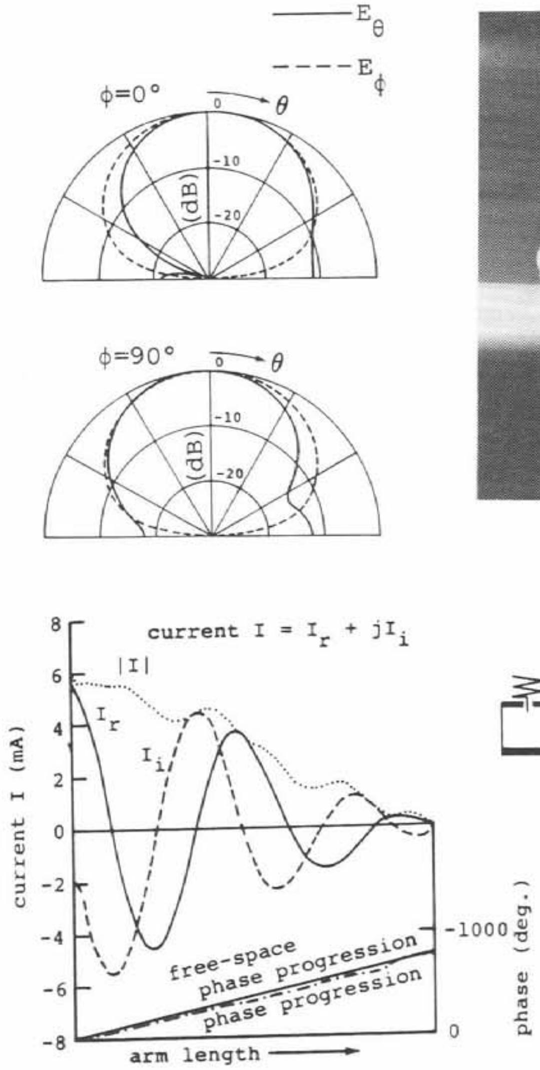
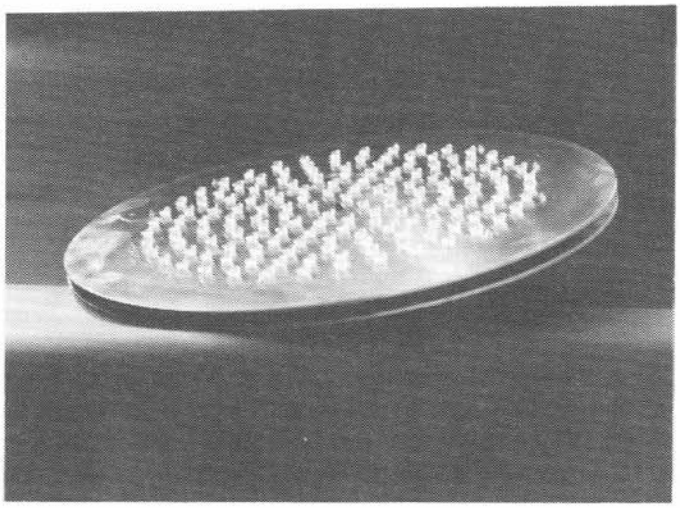


Fig.5 Current distribution and radiation pattern (n=2).



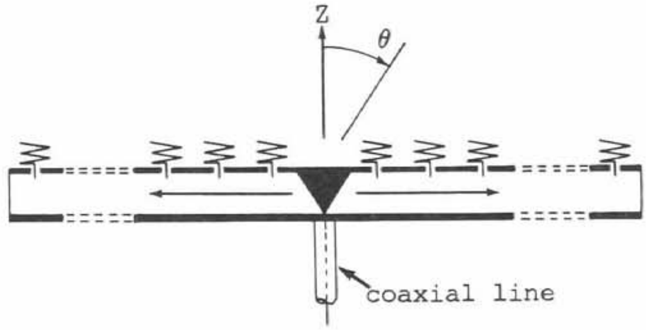


Fig.7 A flat type antenna consisting of low profile helices.

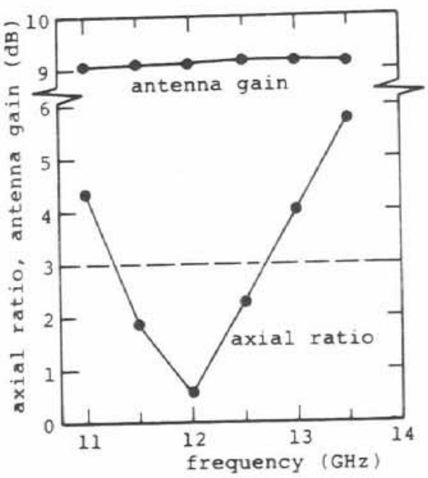


Fig.6 Frequency responses of axial ratio and antenna gain (n=2).

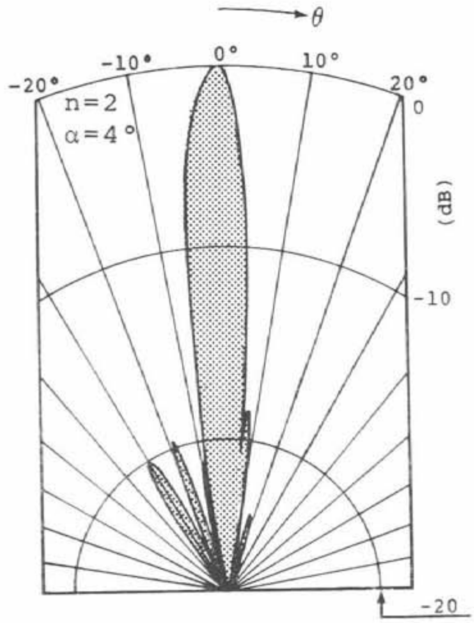


Fig.8 Measured radiation pattern