Radiation Efficiency of Multi-arm Open-ended Spherical Helix Antennas

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***Abstract*—Radiation efficiency of multi-arm open-ended spherical helix antennas has been discussed in this paper. The numerical electromagnetics code (NEC) engine has been utilized for the calculation of their radiation efficiency. It has been found that single-arm Kim-type winding antennas can achieve higher radiation efficiency than that of the Best-type antennas, and non-feeding multi-arms can increase their radiation efficiency.**

***Index Terms*—radiation efficiency, spherical helix antenna, off-center feeding.**

1. Introduction

Since the theoretical Q limit of electrically small antennas has been studied by many authors, many antennas on spherical surface have been proposed to approach their Q limits. Best proposed the spherical helix antennas with and without ground plane [1], [2], and other type of the spherical helix antennas has been proposed by Kim [3], [4]. However, the radiation efficiency of these antennas has not been discussed yet so far.

In this study, the radiation efficiency of Kim and Best-type spherical helix antennas is numerically calculated and compared. Multi-arm open-ended spherical helix antennas are proposed, and the radiation efficiency of their antennas is also computed.

2. Multi-arm Open-ended Spherical Helix Antennas

Let us consider both Best-type and Kim-type antenna as shown in Fig. 1. Geometries of these antennas are defined in Refs. [1], [4]. These antennas can achieve self-resonance at a desired frequency by varying the pitch angle. Simple structure is one of the advantages of the Best-type antenna, whereas the Kim-type antenna has a constant ratio of the theta- to phi-components of the current distribution.

Numerical calculation has been done to find the radiation efficiency of the spherical helix antennas. An example of one-arm Kim-type spherical helix antenna is shown in Fig. 2. All of spherical helix antennas have the same antenna radius $R = 40.0\,\mathrm{mm}$, and the diameter of the copper wire is $1.0\,\mathrm{mm}$. The antennas were modeled using the numerical electromagnetics code (NEC) engine of 4NEC2 [5].

The difference of the direction of the helical wire between Kim- and Best- type antennas affects the radiation efficiency at the same electrical size (resonance frequency). Single-arm Kim-type antenna can achieve higher radiation efficiency than that of Best-type antenna, as shown in Fig. 3.

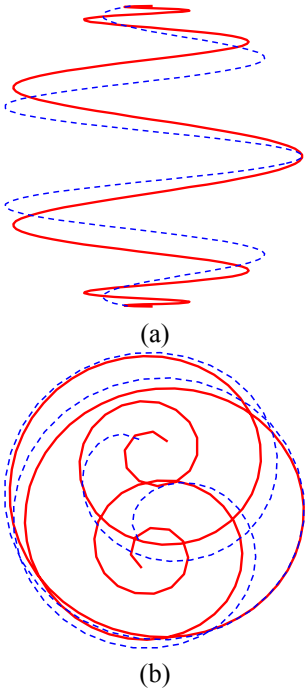
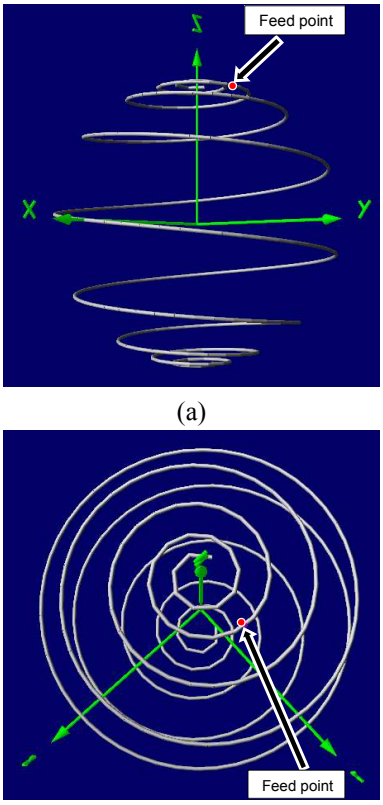


Fig. 1. Comparison of the shape of Kim and Best type helix antennas ($kR = 0.2$). ——: Kim-type antenna; - - -: Best-type antenna. (a) Side view. (b) Slanted top view.

Multi-arm open-ended structures have been employed to accomplish higher radiation efficiency than that of a single-arm case. An example of two-arm open-ended spherical helix of Kim-type is depicted in Fig. 4. Conventionally, multi-arm *folded* spherical helix antennas are introduced to increase the input impedance [1], [2]. However, it may be difficult to control the input impedance because of a discrete integer number of the multi arms. When these folded arms are disconnected to be open-ended, the feeding element can freely determine its input impedance in regardless of the number of arms. In order to illustrate the effect of the number of arms, the radiation efficiency of the 50 ohms multi-arm open-ended spherical helix antennas is shown in Fig. 3. From this figure, the antennas can achieve higher radiation efficiency if the arms are increased.



(a) (b)

Fig. 2. One-arm open-ended Kim-type spherical helix antennas. The input impedance is tuned approximately to 50 ohms by using the off-center feeding. $kR = 0.13$. (a) Side view. (b) Slanted top view.

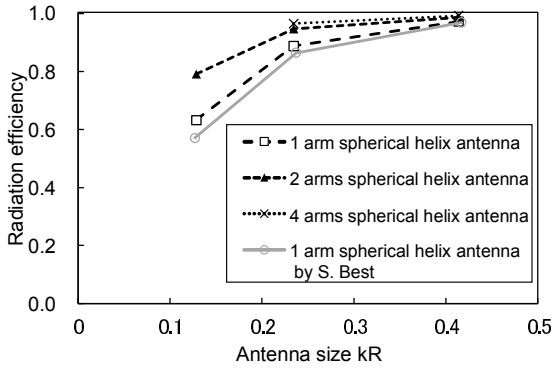
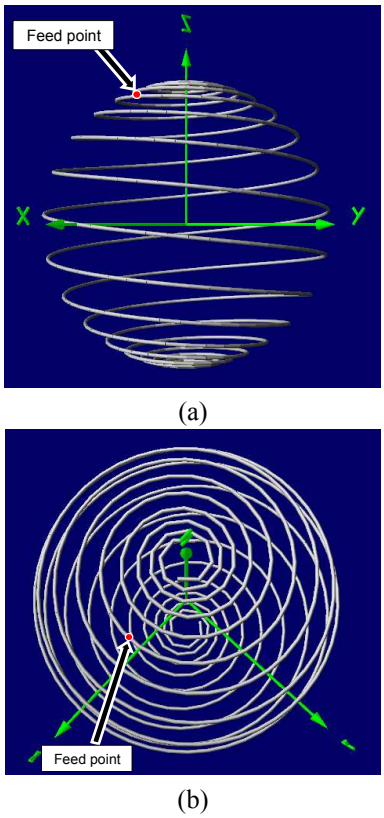


Fig. 3. Radiation efficiency of the spherical helix antennas with multiple arms.

3. Conclusion

The radiation efficiency of the Kim- and Best-type antennas has been calculated by using the numerical simulation. It has been shown that single-arm Kim-type antennas can achieve higher radiation efficiency than that of Best-type antennas and non feeding multiple arms can increase the radiation efficiency. Detail analysis as well as its theoretical background should be investigated further.



(a) (b)

Fig. 4. Two arms open-ended Kim-type spherical helix antennas. The input impedance is tuned approximately to 50 ohms by using the off-center feeding. $kR = 0.13$. (a) Side view. (b) Slanted top view.

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