A Low-profile, Single-Arm Hexagonal Spiral Arrays With a 3:1 Bandwidth on Ground Plane

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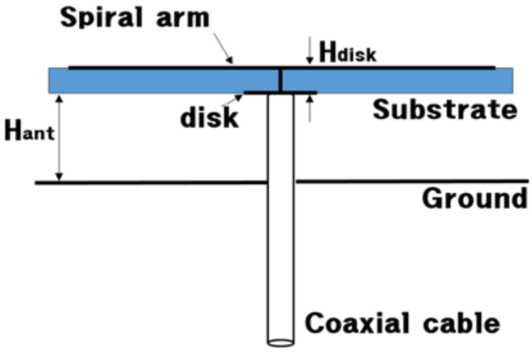
***Abstract*—We present a low profile, single-arm hexagonal spiral arrays having a 30° beam scan without grating lobe operating 3:1(2 to 6 GHz) bandwidth placed on a ground plane. The arrays are composed of regular hexagonal spirals fed by 50 Ohm coaxial cable. As array elements are very tightly coupled like 'honeycomb' structure, the mutual capacitance introduced by inter-element can compensate the inductive effects caused by ground plane. A wideband arrays can be designed having a low profile (0.08λ at 2GHz), 3:1 bandwidth, 30° scan angle with below -10dB side lobe level.**

Keywords—wideband antenna array, single arm spiral, low profile antenna

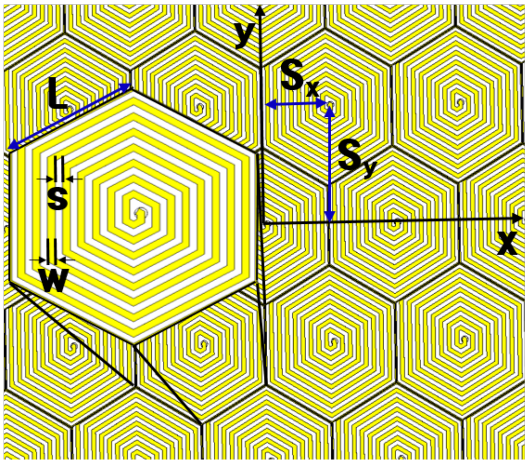
I. Introduction

Since Rumsey introduced the spiral antenna, it have been used in various military and commercial applications due to its inherently wideband property[1]~[2]. However, because of its relatively low gain and broad radiation pattern, an antenna array is required to meet the demands of high gain and scan beam. For the implementation of wideband array without grating lobe, physically small antennas are required. Another way to make wideband array antenna is shown in [3]~[4]. But, WAVES (wideband array with variable element sizes) has in general a complicated structure.

In this paper, we design a low profile, simple feeding, single-arm hexagonal spiral antenna arrays placed on ground plane. This antennas have some distinguishing features. First, unit element is arranged in triangle lattice like 'Honeycomb' structure for reducing inter-element spacing. Second, antennas arm is fed by a 50 Ohm coaxial cable without balun circuit, necessary for a typical two arm, self-complementary spirals. Third, antenna height(an interval between antenna and ground plane) is extremely low compared to a conventional spiral antennas, which have λ/4 height. Spiral antennas have bi-directional radiation pattern. But, most practical case, uni-directional radiation pattern is needed. A uni-directional radiation pattern is obtained by backed a conducting plane[5] or cavity[6]. But, ground plane restricts spiral's wideband characteristic due to inductive effect. Thus, we densely arrange elements to introduce capacitance that mitigate inductive effect. SectionⅢ present simulation result compared to single element and 2D infinite arrays.



a)



b)

Fig. 1. a) Side view of unit element b) array with hexagonal spirals

II. Unit Element Configuration

The unit element is depicted in Fig. 1. Unlike the conventional spiral antenna, single-arm hexagonal spiral antenna is fed by 50 Ohm coaxial cable. Inner conductor of the coaxial cable is connected to center of the spiral arm and outer conductor of the coaxial cable is connected to the disk[7]. The disk size is smaller than the highest frequency radiation region[7]. The spiral arm is placed on 1mm thick dielectric substrate (ε_r=4.3), where an antenna height (H_{ant}) is 12.5mm (0.08 wave length at the lower frequency of 2 GHz). The shape of unit element is regular hexagon with side length(L) of 19.2mm and arm width (w) and spacing (s) of 1mm as shown in Fig. 1. Exceptionally, the outermost arm width (w_o) and spacing (s_o) are 0.2mm and 0.8mm, respectively[8]. The unit element is arranged in 2D infinite array.

III. ARRAY SIMULATION

When the spiral antenna is placed on the ground plane, the low frequency performance is deteriorated by the inductance introduced by the ground plane. Then, wideband characteristic of the spiral antenna is limited. To restore low frequency performance, unit elements are tightly arranged like 'honeycomb' structure. The capacitance caused by tightly coupled array between unit elements mitigates inductive effect[8]~[9]. Fig. 2. definitely shows VSWR enhancement of infinite arrays in low frequency range compared to a single element at antenna height 12.5mm (H_{ant} / λ = 0.08 λ at the lowest frequency 2 GHz).

An array antennas have inherently narrow bandwidth, since electrical distance between elements alters by frequency. Therefore, it is important to reduce inter-element spacing to implement broad bandwidth. A scan angle 30° at 6 GHz is investigated, as a shortest inter-element spacing case. The condition for avoidance of grating lobe is given by

$$\frac{d}{\lambda} < \frac{1}{1+\sin|\theta|} \tag{1}$$

Where d is the inter-element spacing, θ is the scan angle. Hence, For scan angle 30° at 6 GHz without grating lobe, d < 33.3mm is required. The inter-element spacing to x-axis S_x and y-axis S_y have different value each other ($S_x = \sqrt{3}L/2$, S_y = 1.5L, L=19.2mm), but they satisfy the aforementioned condition. Fig. 3 shows SLL of x-axis and y-axis at 30° scan angle. SLL of both side is below -10dB in operating frequency range 2 ~ 6 GHz. Grating lobe does not occur. The side lobe level at x-axis is lower than y-axis, since x-axis inter-element spacing is smaller than y-axis.

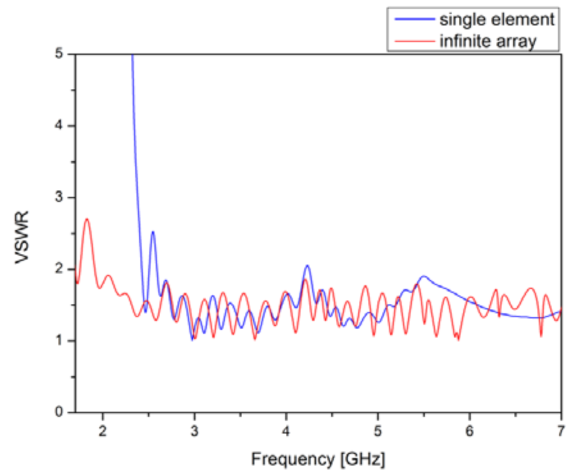


Fig. 2. Simulated VSWR of single element and infinite array

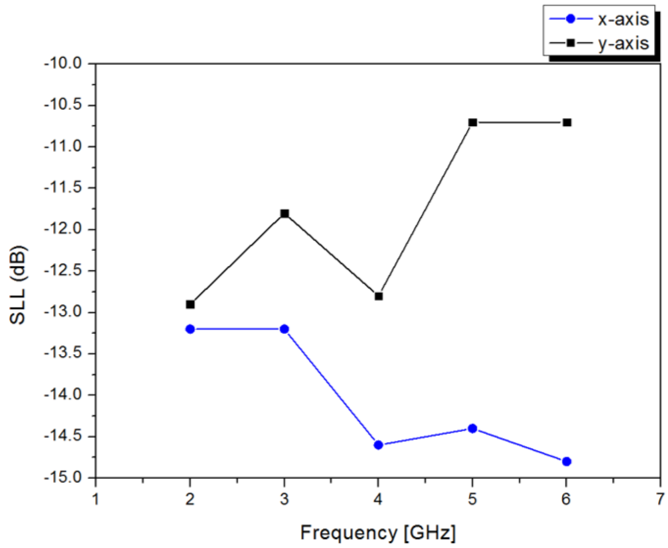


Fig. 3. SLL of x-axis and y-axis at 30° scan angle

IV. CONCLUSION

A low profile, simple feeding, single-arm hexagonal spiral antenna arrays is proposed. It can steer the beam up to 30° in both azimuth and elevation angle with 3:1 bandwidth. The hexagonal spiral is backed by a small disk and excited by 50 Ohm coaxial cable without balun circuit. Thses arrays have 'honeycomb' arrangement for reducing element spacing in order to increase the capacitive coupling between antenna elements. This capacitance can mitigate inductance caused by ground plane.

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