A 1×2 DIELECTRIC-LOADED HELICAL ANTENNA ARRAY

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Introduction: The helical antenna has been regarded as a broadband circular polarized radiating structure with relatively high gain since 1947 [1]-[3]. To facilitate its application in the mobile satellite communication, a cylindrical dielectric resonator (DR) can be utilized to enhance the forward tilt of the total electric field launched from the helix. This paper reports the design of a 1×2 linear cylindrical DR-loaded helical antenna array in the C-band. The helix is used to feed the wave to a long cylindrical rod of DR which is loaded axially along the axis of the helical core. The wave is launched and propagates towards the tip of the tapered end. Because of the surface-wave effect, the wave will cling to the DR surface and its energy is kept from spreading out. For a properly designed tapered end, wave reflected back from the tip is negligibly small. Energy is radiated in the axial direction within a small solid angle. The dielectric cylinder changes the radiation pattern of the antenna and therefore its directivity. In fact, the directivity of the helix is enhanced by the wave guiding effect. Presence of an electrically dense material inside the helix also alters the effective phase velocity. It is expected that the effective wavelength λ_e is longer than λ_o but shorter than λ_d, the wavelength in the dielectric medium. Hence, the diameter of the helical antenna is increased by the dielectric cylinder [4]-[7]. Size enlargement is an important feature in the design of an antenna for a satellite-based mobile communication in the C-band. Even when low-orbit satellites are used, the field strength on earth will be very weak. Thus, a large aperture is needed to intercept the extremely feeble incident field. In this paper, the radiation patterns of the unloaded helical antenna, DR-loaded helical antenna and a 1×2 DR-loaded antenna array are compared. The effects of the inter-element spacing, the antenna gain, the VSWR and the axial ratio of the antenna array are also measured.

Array configuration: The 1×2 dielectric-loaded helical antenna array is shown in *Fig.1*. The pitch angle, the circumference and the number of turns of the helical wire are 10°, 3.95cm and 15 respectively. The antenna is mounted on an electrically large ground plane. The helix is base-fed at the ground plane and it is designed to operate in the axial mode. The diameter of the helix and the spacing between two adjacent turns are appropriately chosen such that the phase change between turns is 2π. The helix resembles a traveling-wave antenna and the electromagnetic wave would move towards the dangling end of the helix. The relative permittivity of the dielectric cylinder ε_r is 9 times higher than unity, and its dielectric loss is negligibly small. In order to reduce wave reflection at then end, the diameter of the dielectric cylinder is gradually reduced to form a tapered tip. The DR is 6 turns of spacing above the ground plane. The axial length of the DR equals 13.1cm. A copper wire of 1.0mm cross-sectional diameter is used for the helical wire and the cross-sectional diameter of the helix core is about 0.1mm larger than that of the DR.

1. Radiation Pattern: *Fig.2A* shows the radiation pattern of the helical antenna without the dielectric waveguide when the frequency of measurement is 4GHz. The HPBW is 44° and the antenna gain is 8.7dBi. After including a DR rod, the HPBW reduces to 39° and the radiation pattern is shown in *Fig.2B*. The antenna gain is 10dBi. It verifies that the assumption of the

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gain enhancement by the DR guiding effect is valid. For the design of 1×2 array, the radiation pattern is shown in *Fig.2C*. The HPBW further reduces to 35° and the antenna gain is 12.13dBi. It can be seen that the 1×2 antenna array possesses a better radiation directivity when compared to the former two 1×1 antennas.

2. Inter-Element Spacing: When the distance between two antenna element is changed, the gain at the frequency of operation varies and is shown in *Fig.3*. It is seen that the gain comes to a local maximum at an inter-element distance d of 1λ. Afterwards, the gain comes to a peak at $d = 2\lambda$. For $d > 2\lambda$, the gain just changes slightly. The flatten shape after d=2λ may be due to the fact that the coupling effect between the antenna elements becomes negligibly small. Hence we see that the array obtains the most desirable performance at d=2λ.

3. Gain Performance: From *Fig.4*, when the distance between the 2 antenna elements is 2λ, the peak again is 11.8dBi at 3.88GHz. When considering 4GHz as the frequency of operation, the gain is about 12.13dBi and the 3dB bandwidth is about 550MHz (3.75GHz ~ 4.3GHz). When the distance between elements is 1λ, the peak gain is 9.8dBi at 4.2GHz. The gain at 4GHz is 9dBi. And the 3-dB bandwidth reference to this frequency is 570 MHz (3.75GHz ~ 4.32GHz).

4. VSWR: The VSWR responses of the 2×1 helical antenna array are shown in *Fig.5A* and *Fig.5B*. For d = 2λ, the VSWR bandwidth is about 1.75GHz (3.25GHz ~ 5GHz). For d = 1λ, the bandwidth for VSWR<2 is about 1.45GHz (3.25GHz ~ 4.7GHz). Compared to 1λ, the 2λ distance gives a wider VSWR bandwidth. It covers extra frequency band from 4.7GHz to 5GHz.

5. Axial Ratio: The axial ratio is nearly zero from 3.8GHz afterwards. For the 1×2 array, the axial ratio for the conventional helical antenna varies between +2.0 and -1.0dB in the direction of the helical core, indicating nearly circular polarization in this direction.

Conclusion: A cylindrical rod of dielectric resonator (DR) is used as a surface-wave guiding structure to enhance the radiating performance of the helical antenna. The design is proved to be successful when the radiation pattern is found to have its HPBW reduced and possess a better gain performance. A 1×2 linear antenna array has been constructed and a good axial ratio is observed. A inter-element spacing of 2λ in the array design gives the most stable and satisfactory frequency response. It is thus concluded that the DR-loaded version of the helical antenna array provides a valuable means to enhance the utilization of the antenna in the mobile satellite communication.

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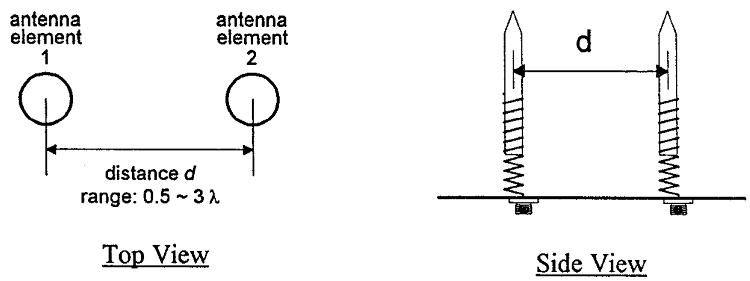

Fig.1. Top View and Side View of the 1×2 Linear Array

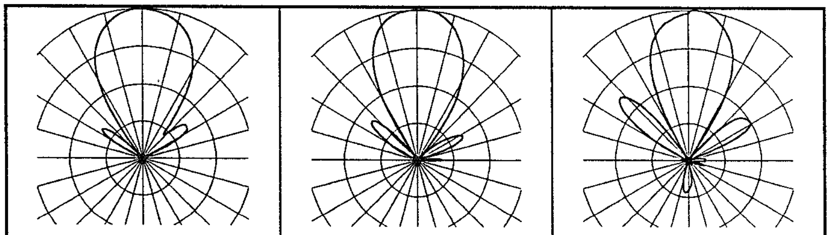

Fig.2A *Helical Antenna without DR*	*Fig.2B* *Helical Antenna with DR*	*Fig.2C* *1×2 Dielectric-Guided Helical Antenna*

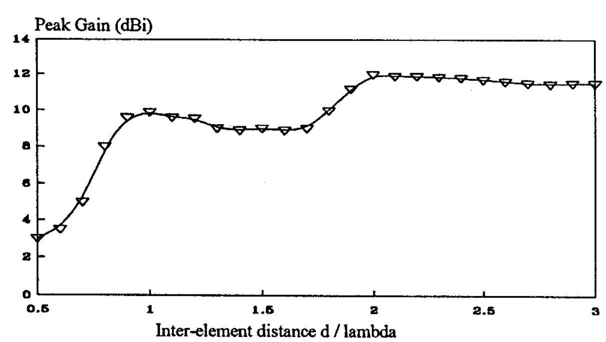

Fig.3 The Maximum Gain With Varying Inter-Element Distance In The 1×2 Array

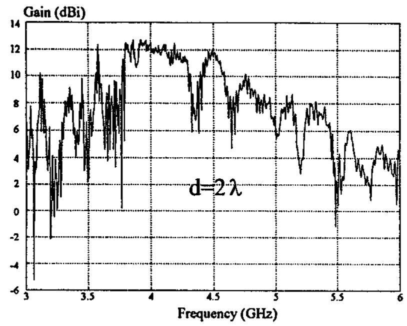

Fig.4A Gain of 1×2 Array with d=2λ

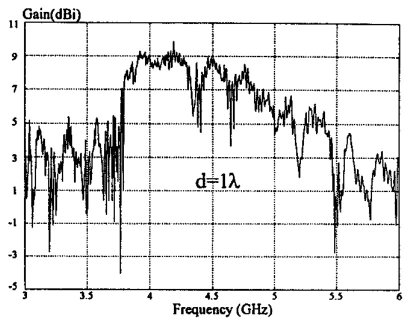

Fig.4B Gain of 1×2 Array with d=1λ

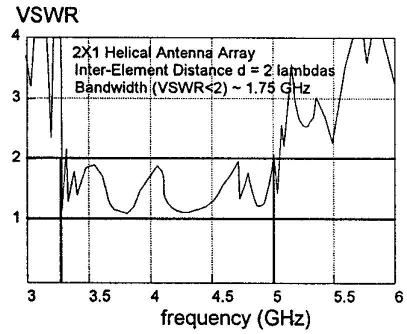

Fig.5A VSWR of 1×2 Array with d = 2λ

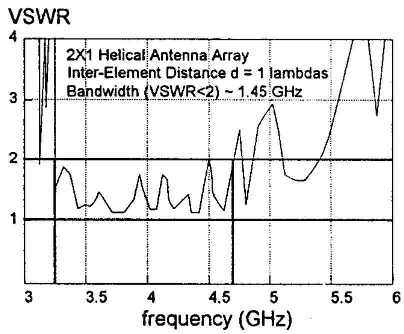

Fig.5B VSWR of 1×2 Array with d = 1λ

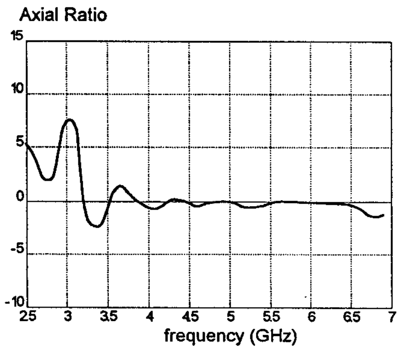

Fig.6 Axial Ratio of the 1×2 Array