A CYLINDRICAL DR ROD ANTENNA FED BY A SHORT HELIX

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I) INTRODUCTION: The use of electrically dense materials as antennas has been a subject of hot research. Mueller and Tyrrell used polystyrene to constructed dielectric rod antennas [1] and came up with some empirical formulas. More recently, Chatterjee [2] has provided a very comprehensive investigation of various types of dielectric antennas, including dielectric rod antennas. The authors have also constructed a dielectric-loaded helical antenna and provided a method of analysis [3]. However, as the authors has pointed out [3], dielectric-loaded helical antennas have only a marginal increase in performance over helical antennas. This may be due to some uncompromising characteristics between a helical and a dielectric antennas. A dielectric rod antenna has been shown to have a high directivity and a helical antenna is inherently relatively high-gain and circularly polarized [4]. A suitable method can be used to put them together so that desirable characteristics are obtained. In this paper, we use a short helix to feed a DR (Dielectric Resonator) rod antenna. The helix itself is in turn excited by a coaxial cable. It is found that high directivity as well as circular polarization are resulted. The use of the helix greatly simplified the feeding mechanism of the DR rod while also provided a circularly polarized source which other conventional methods such as waveguide feeding cannot. When suitable frequency electromagnetic waves were excited, the high permittivity DR rod acted as an effective traveling wave antenna so that high gain was obtained. This antenna retains the characteristics of both the helical and DR rod antennas. It was reported recently that an aperture-coupled helical antenna has been designed [5]. It can be immediately envisaged that this design has the advantage of ease for helix array constructions. The novel structure can be employed in our feeding helix so that an extremely high gain DR rod antenna array can be constructed for satellite communications. In our preliminary study, we measured the antenna's VSWR, radiation pattern, bandwidth and axial ratio. The operating frequency has been chosen to be in the C-band.

II) ANTENNA CONFIGURATIONS: The helix driven DR rod antenna is shown in Fig. 1. The feeding helix is C cm in circumference and wound with a copper wire of d mm in diameter. The pitch angle of the helix is α. The helix is wrapped 3-turn around the DR rod and is connected to a coaxial cable. The diameter of the cylindrical DR rod is D and the permittivity is ε_r. The total length of the DR rod including a tapered head at one end is $L1 + L2$. The whole antenna is mounted over a large ground plane with a hole on it for fixing the DR rod.

III) MEASUREMENT RESULTS AND DISCUSSION: The antenna characteristics were determined experimentally for the following set of parameters: $C = 4.84$ cm, $d = 0.7$ mm, $\alpha = 13°$, $D = 1.47$ cm, $\varepsilon_r = 9.0$, $L1 = 2$ cm and $L2 = 20$ cm. The short helix operates in the axial mode for the frequency range from 4.65 GHz to 8.26 GHz ($3/4 < C/\lambda < 4/3$, where λ is the free-space wavelength). However, this range will be shifted down due to the presence of the DR rod [3]. Normal mode operation of the feeding helix ensures that most of the power is directed along the DR rod. According to Kraus [4, pp.686], for the lowest mode (TE_{11}) to be guided along the a circular waveguide, the waveguide diameter must be greater than

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$0.58\lambda / \sqrt{\varepsilon_r}$. This indicates that for our antenna, efficient power transmission along the DR rod will take place only when the operating frequency is greater than

$$\frac{0.58c}{D\sqrt{\varepsilon_r}} = 3.95\ GHz$$

where c is the velocity of light in free-space. The reason for the use of a relatively high permittivity (ε_r = *9.0*) DR is to increase the guiding effect of the DR rod. DR material is also low-loss at high frequency so that efficiency is guaranteed

The VSWR versus frequency measured with reference to a *50 Ω* transmission line is shown in Fig. 2. It can be seen that from *4.5 GHz* to *5.0 GHz* and from *6.0 GHz* to *7.0 GHz*, the VSWR closely follows that of an unloaded helix [4]. The relatively large mis-match between *5.0 GHz* to *6.0 GHz* has been intentionally investigated and it was found that this mis-match is mainly due to the straight portion of the helix leading from the coaxial connector to the DR rod. It was further observed that the values of the VSWR in this region could be significantly reduced by increasing the angle subtended by the straight portion with the ground plane to a suitable value and which in our antenna is about *30°*.

The relative power received versus frequency is shown in Fig. 3. The source used in the measurement was linearly polarized. Fig. 4 shows the case when the antenna is rotated *90°*. Both graphs show a relatively stable region between *4 GHz* and *5 GHz*. Hence the bandwidth is about *1.0 GHz*. This is quite a broadband although it is only *28 %* of the axial mode frequency range of the helix. We also see that the downshift of the operating frequency by the DR rod is slightly different for the two orthogonal polarization directions. This difference is about *0.3 GHz* if we count the lower cutoff frequency to be where the relative power received is *3 dB* below the highest relative power received in the operation bandwidth.

By definition the axial ratio is the ratio of the major axis to the minor axis of the polarization ellipse. A reasonable estimate of this ratio is the difference between the values of Fig. 3 and Fig. 4 and it is plotted in Fig. 5. Again we see that the axial ratio in the axial direction fluctuates within *3 dB* in the frequency range from *4 GHz* to *5 GHz*. This demonstrates a relatively pure circular polarization in this frequency range. Outside this range, general elliptical polarization is observed.

The radiation patterns at 3 different frequencies over the operation bandwidth are shown in Fig. 6. As the frequency increases, the half-power beam width (HPBW) decreases while the sidelobe levels increase. Using the HPBW empirical formula given in [1] for polyrod antennas, i.e., $HPBW = 60°/\sqrt{L_\lambda}$ where L_λ is the length of polyrod in free-space wavelength, we can estimate the HPBW for our DR rod antenna. That is

frequency	estimated	measured	error
4.0 GHz	*39°*	*41°*	*4.9%*
4.3 GHz	*37°*	*38°*	*2.6%*
4.6 GHz	*36°*	*36°*	*0%*

It can be seen that although our DR rod antenna is relatively short ($L_\lambda < 3$), the directional character of the radiation pattern is already very obvious. A radiation pattern of the feeding helix is shown in Fig. 7 for comparison.

Rigorous theoretical analysis of the DR rod antenna is very complicated. However, numerical solutions based on the volume integral formulation [6] are still possible provided that a fast and large memory size computer is available.

IV) REFERENCES

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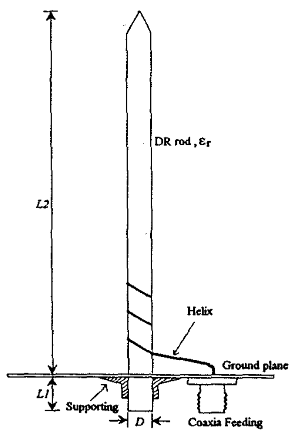

Fig. 1 The configuration of the cylindrical DR rod antenna fed by a short helix

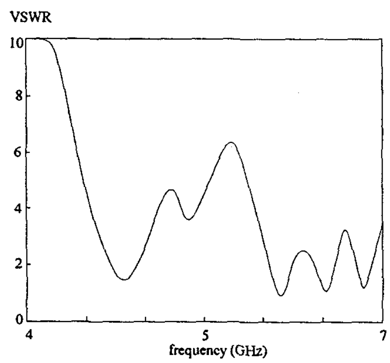

Fig. 2 The VSWR of the DR rod antenna

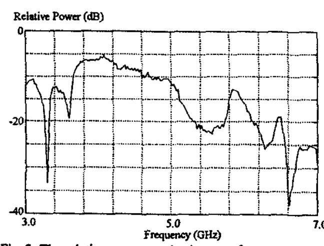

Fig. 3 The relative power received versus frequency ($\phi = 0°$)

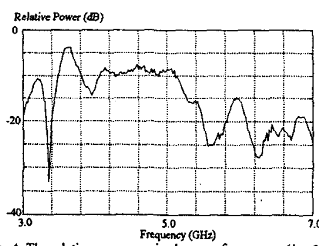

Fig. 4 The relative power received versus frequency ($\phi = 90°$)

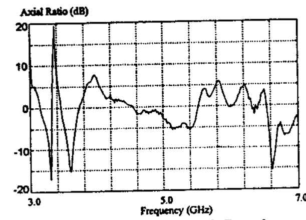

Fig. 5 The axial ratio of the DR rod antenna.

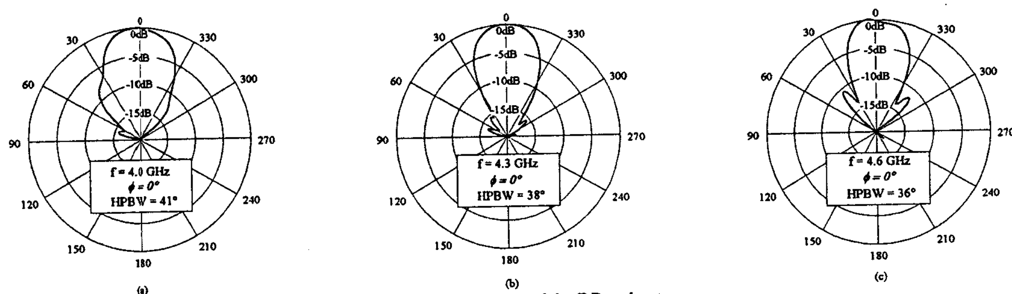

Fig. 6 Radiation patterns of the DR rod antenna

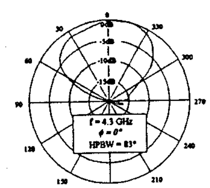

Fig. 7 A radiation pattern of the short feeding helix