RADIATION PATTERN MEASUREMENTS OF A DELTA-LOOP ANTENNA AT 1000 MHz

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ABSTRACT

Delta-loop antennas with centre-feed and apex-feed were constructed of solid aluminium conductor and aluminium tube with arm lengths of 30 cm each. Radiation pattern measurements on delta-loop antennas were made at 1000 MHz. The vertically oriented delta-loop antenna provided a highest gain of 24 dB in contrast to a lowest gain of 12.5 dB of a horizontally oriented delta-loop antenna.

1.0 INTRODUCTION

The ultra-high-frequency (UHF) range covers frequencies from 300 to 3000 MHz and is used for television, satellite communication, navigation and radar signals (1). Above the frequency of 300 MHz, the wavelength of electromagnetic signals becomes less than one metre. At such frequencies (called microwaves), the antenna length is of the order of the signal wavelength.

Electrically small antennas (where the loop length is small compared to the signal wavelength) have low efficiency and are used where high efficiency is not very important, i.e., in direction finding. However, as the length of the loop is increased and it becomes comparable to the signal wavelength, the efficiency increases and the antenna can be used for transmission. In most cases, the antenna is designed to operate with the loop length close to one wavelength (2).

Among the various types of antennas are the loop antennas. The most widely used loop antennas are the circular-loop and the square-loop antennas. Compared with the circular-loop and the square-loop antennas, the delta-loop (Δ)antenna has better mechanical strength and possesses a more stable structure. The delta-loop is made up of three equilateral arms and can be fed at the apex or at the centre (2).

The important characteristics of any antenna are its impedance variation and its radiation pattern. The impedance variation of a delta-loop antenna is similar to the impedance variation of a square-loop antenna (2, 1).

The frequency of operation was chosen close to 1000 MHz (1 GHz) because it is in UHF range near the L band (1 and 2 GHz) and the available signal generator could provide frequencies up to 1000 MHz only.

Results of impedance variation of a delta-loop antenna have already been published (2) and this paper now presents the results of radiation pattern measurements of a delta-loop antenna.

2.0 RADIATION PATTERN

The power gain of an antenna is defined as the ratio of the power received $P(\Theta,\phi)$ to the power per unit solid angle P_i radiated by a loss-less isotropic radiator. The gain function $G(\Theta,\phi)$ is (3)

$$G(\Theta,\phi) = \frac{P(\Theta,\phi)}{P_i} \qquad (1)$$

where Θ is the angle from the vertical z axis and ϕ is the angle in xy plane from the x axis.

For most antennas, the gain function has a well defined maximum value denoted by G_m,then the radiation pattern becomes (3)

$$g(\Theta,\phi) = \frac{G(\Theta,\phi)}{G_m} \qquad (2)$$

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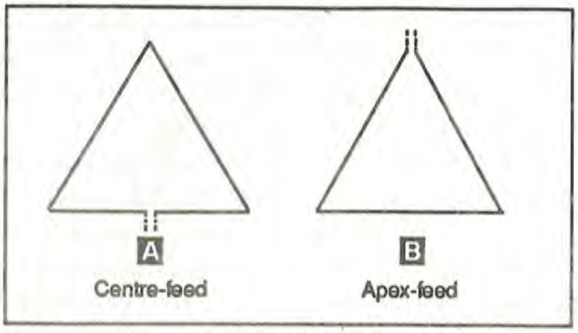

Figure 1: Delta-loop Antennas

The radiation pattern is thus the gain function normalised to its maximum value G_m. When the gain function is plotted, a three-dimensional plot results. In practice, two-dimensional diagrams are often used (3).

Complicated antenna structures are not amenable to analytical solution of radiation patterns. Instead, it is always much more reliable to test the antenna for field performance. Hence, it was decided to make radiation pattern measurements on the delta-loop antennas.

3.0 EXPERIMENTAL MEASUREMENTS

To compare the performance of the delta-loop antennas, two types of antennas were constructed. Two delta-loop antennas were made of 1/8 inch thickness and half inch diameter aluminium tube. The other two delta-loop antennas were made of solid aluminium conductor rods of 1/6 inch diameter. The aluminium tubes were cut into 32 cm lengths and the solid aluminium conductors were of 31 cm lengths. The ends were argon-welded. One tubular antenna and one rod antenna were fed at the centre or base (Fig. 1A). The other tubular antenna and the other solid conductor rod antenna were fed at the apex or top (Fig. 1B). Self-tapping screws were fixed to the feed points so that the RF coaxial cable connection leads can be soldered to the screws on the delta-loop arms. A 50 ohm UHF plug was connected at the other end of the coaxial cable so that the delta-loop antenna was connected through the coaxial cable to the apparatus for making radiation pattern measurements.

The experimental set-up used for measuring the radiation pattern is shown in Fig. 2. The transmitting antenna A is a wide-band log-periodic antenna. From the transmitting antenna, a constant signal power was radiated. The antenna was connected through a coaxial cable to the output of the UHF Signal Generator (Marconi). To improve the accuracy of measurements, the 1000 MHz signal from the UHF generator was modulated by a 1 kHz sine wave signal from the RC

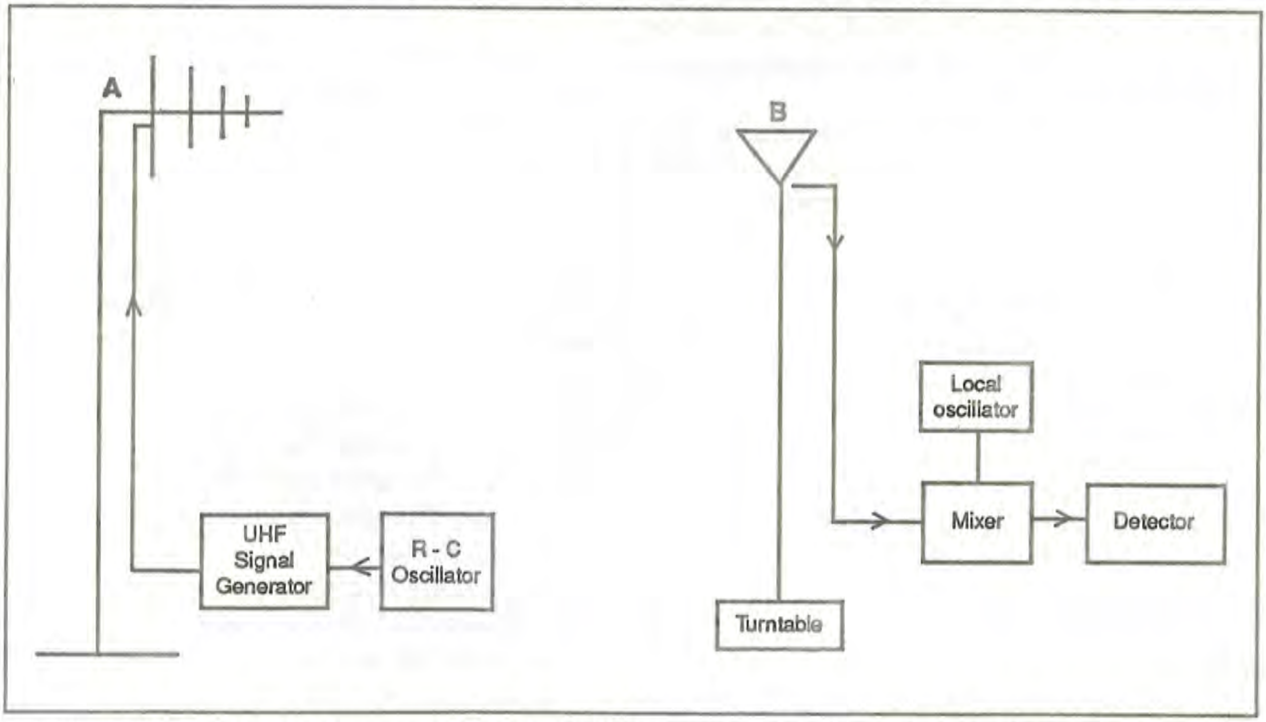

Figure 2: Experimental Arrangement for the Radiation Pattern Measurement of a Delta-loop Antenna

oscillator. The transmitting antenna was placed on the top roof of the Administration building of the University of Nairobi.

The receiving antenna B was placed on the top roof of the Electrical Engineering Department building separated from the Administration building by a few hundred metres. The receiving antenna was mounted on the supporting rod having a fixed turntable (Bruel and Kjaer). By rotating the fixed turntable the orientation of the receiving delta-loop antenna can be changed with respect to the permanently fixed transmitted antenna A. The turntable was marked with one complete circular scale of 360 degrees and could be rotated clockwise.

The receiving antenna B was rotated every 10 degrees and the received signal power was recorded. The local oscillator (General Radio Company) was set to 1030 MHz to give a signal of 30 MHz which was amplified and detected by the 1F Amplifier Unit (General Radio Company).

To calculate the gain of the delta-loop antenna, area enclosed by the radiation pattern was found by using a compensating polar planimeter; and from this area, the radius of the equivalent circle having the same area, was determined. The difference between the peak of the main beam from the centre of polar chart and the calculated equivalent radius gave the gain in decibels. The gain (radiation pattern) which is the ratio of actually received signal power to the isotropic received signal power, is plotted in decibels.

By reciprocity theorem an antenna can be used either in the transmitting mode or in the receiving mode since it is a bilateral, linear, passive network.

4.0 DISCUSSION

The radiation patterns are shown in **Fig. 3** for various antenna orientations as shown by small antenna diagrams drawn outside the polar chart. For the apex-fed solid conductor (rod) delta-loop antenna, the gains are 18.5 dB and 15.5 dB respectively for the orientations A_1 and A_2 shown in Fig 3A. The gain in orientation A_1 is greater by 3 dB than the gain in orientation A_2 because one arm of the antenna is completely vertical; hence the gain is increased.

The polar diagrams of the solid conductor antenna with centre-feed are shown in **Fig. 3B**, where A_1 refers to the horizontal orientation. (A_1 is in the horizontal plane). The gain is 12.5 dB whereas the vertically oriented A_2 (placed in the vertical plane) delta-loop antenna has a much larger gain of 24 dB (**Fig. 3B**). This suggests that the delta-loop antenna provided greater gain in the vertical orientation.

The polar diagram for the tubular delta-loop antenna with centre-feed and horizontal orientation is shown in **Fig. 3C**, the gain is 17 dB. The polar diagram of the tubular centre-feed delta-loop antenna in vertical orientation is shown in **Fig. 3D**, it has a gain of 18 dB. Although the shapes of the radiation patterns vary in both cases, the gains are more or less equal and the vertically oriented delta-loop antenna produces a more symmetrical and more uniform radiation pattern.

The polar diagram of a tubular apex-fed delta-loop antenna with orientation shown in **Fig. 3E** has a gain of 22 dB. Compared to the rod apex-fed delta-loop antenna (gain 18.5 dB), it has a greater gain of 3.5 dB. Therefore, a tubular delta-loop antenna is the preferred choice over the solid conductor delta-loop antenna except for the case where the delta-loop is inverted so as to become a triangular antenna (**Fig. 3B**) with centre feed gain 24 dB. Gain should depend on the orientation.

The vertically-oriented solid conductor delta-loop antennas have gains varying from 15.5 to 24 dB whereas in the case of tubular delta-loop antennas the gains vary from 18 to 22 dB.

The horizontally oriented centre-feed tubular delta-loop has a gain advantage of 4.5 dB over the similar solid conductor delta-loop antenna. These radiation patterns are not symmetrical and show irregularity. This may be due to many disturbing factors.

More experimental results are required to compare with other loop antennas under similar conditions. Theoretical and experimental results on the performance of delta-loop antennas are not available (4).

5.0 CONCLUSION

The delta-loop antennas have gains varying from 12.5 to 24 dB. The gain depends upon the antenna orientation. The delta-loop antenna with vertical orientation provides the highest gain of 24 dB whereas the horizontally oriented delta-loop antenna has the lowest gain of 12.5 dB. Because of skin effect at high frequencies, the performance of a tubular delta-loop antenna will become more reliable and

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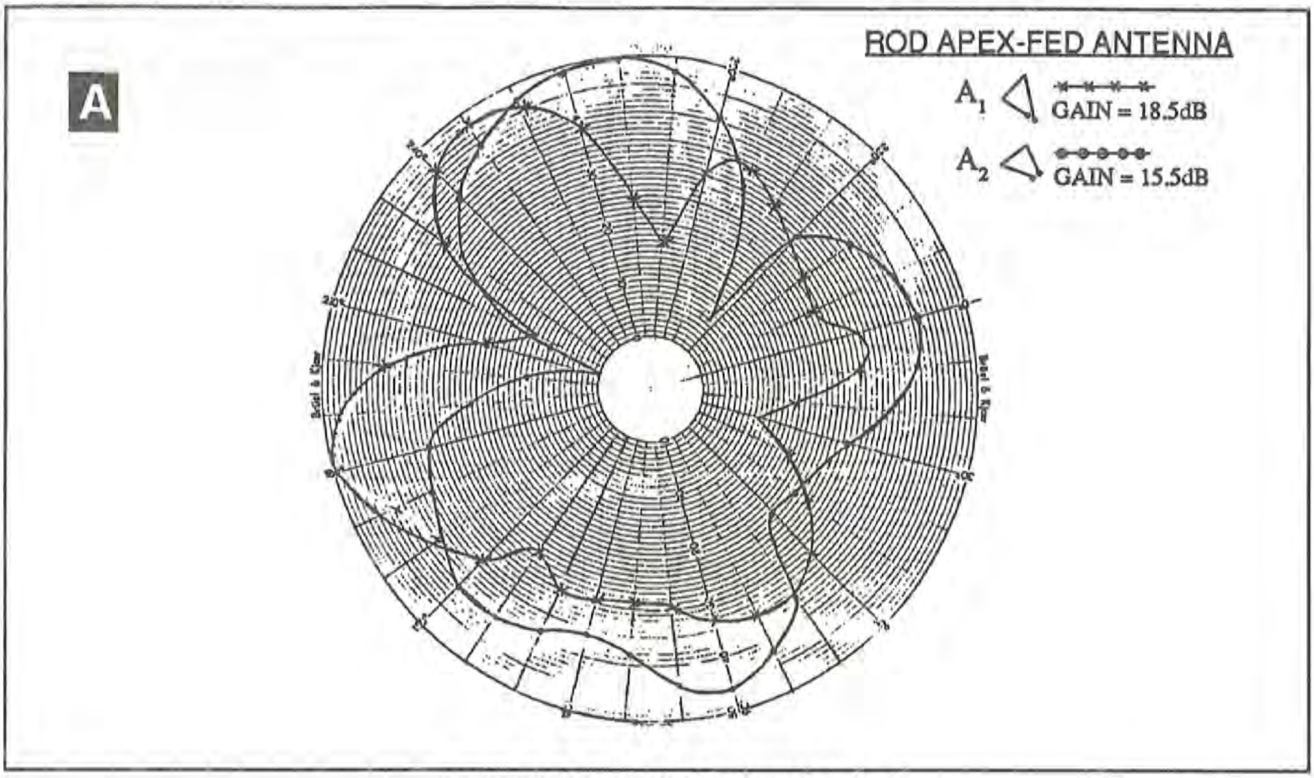

Figure 3 (A): Radiation Pattern Diagram

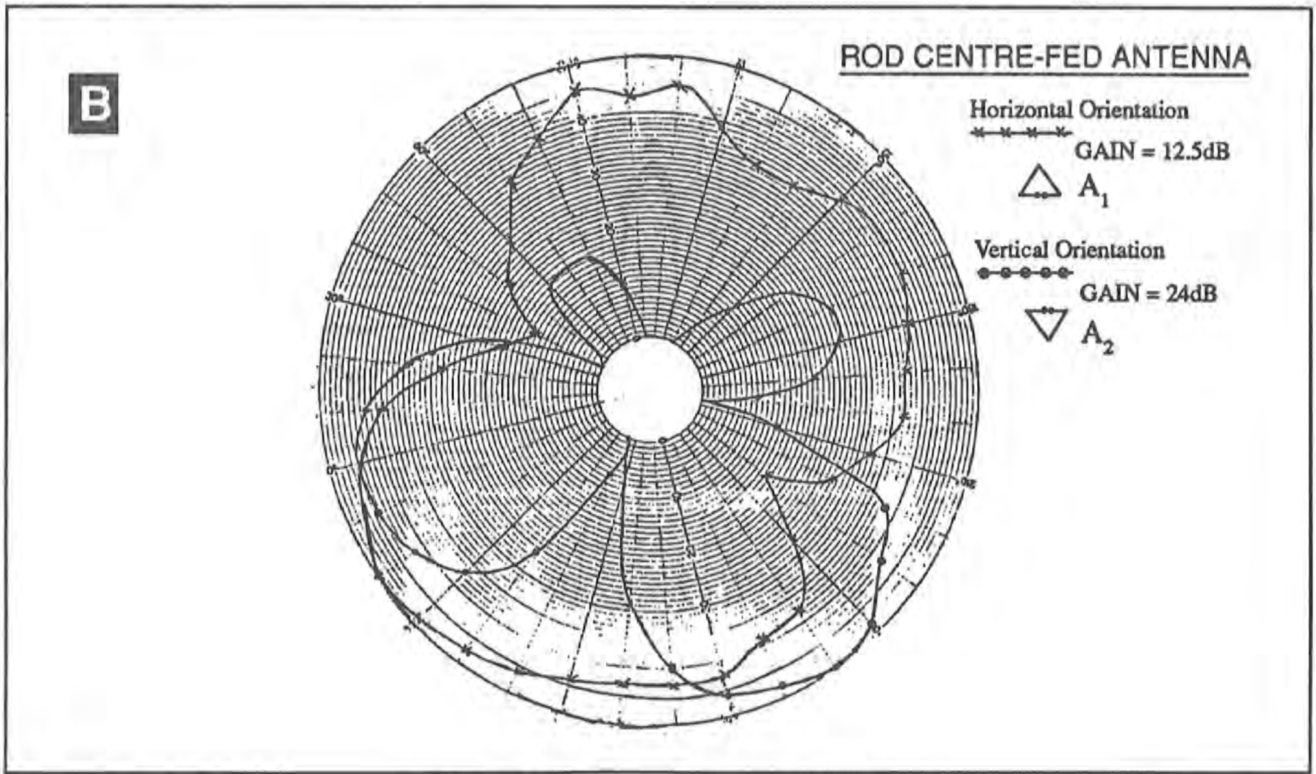

Figure 3 (B): Radiation Pattern Diagram

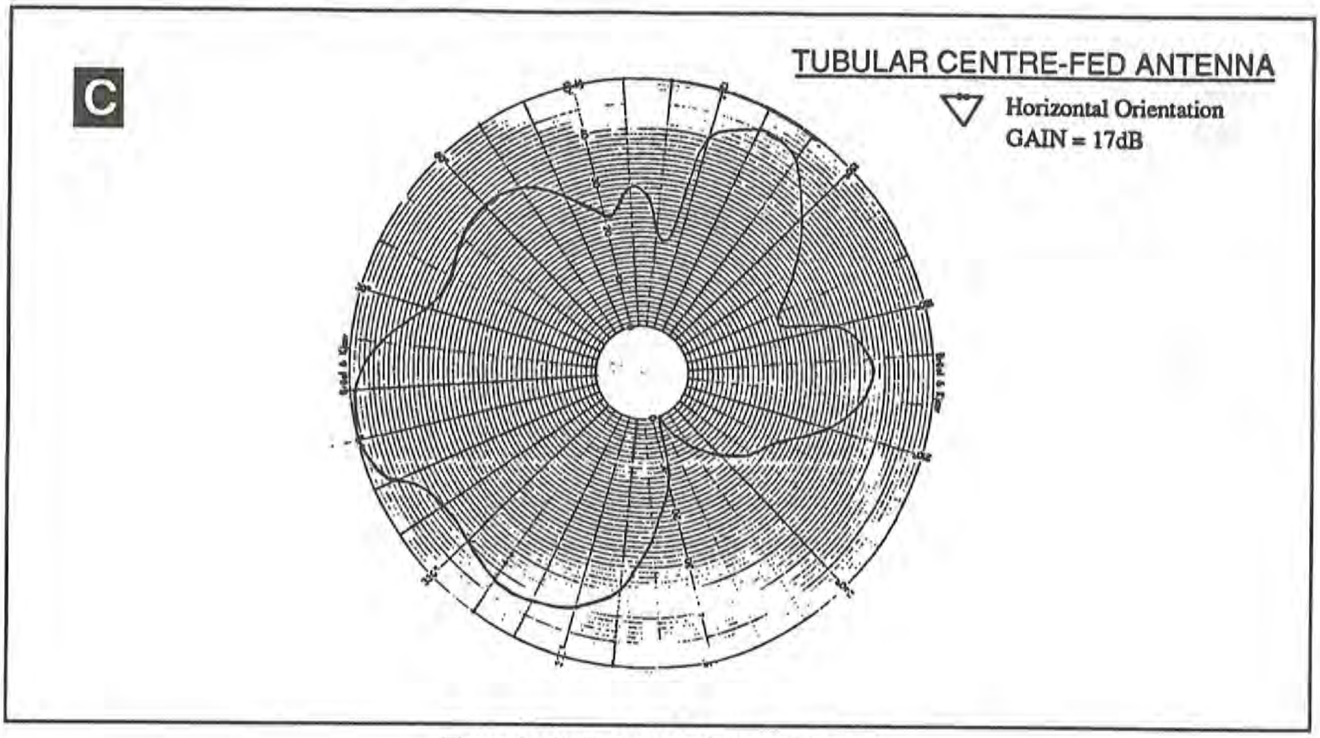

Figure 3 (C): Radiation Pattern Diagram

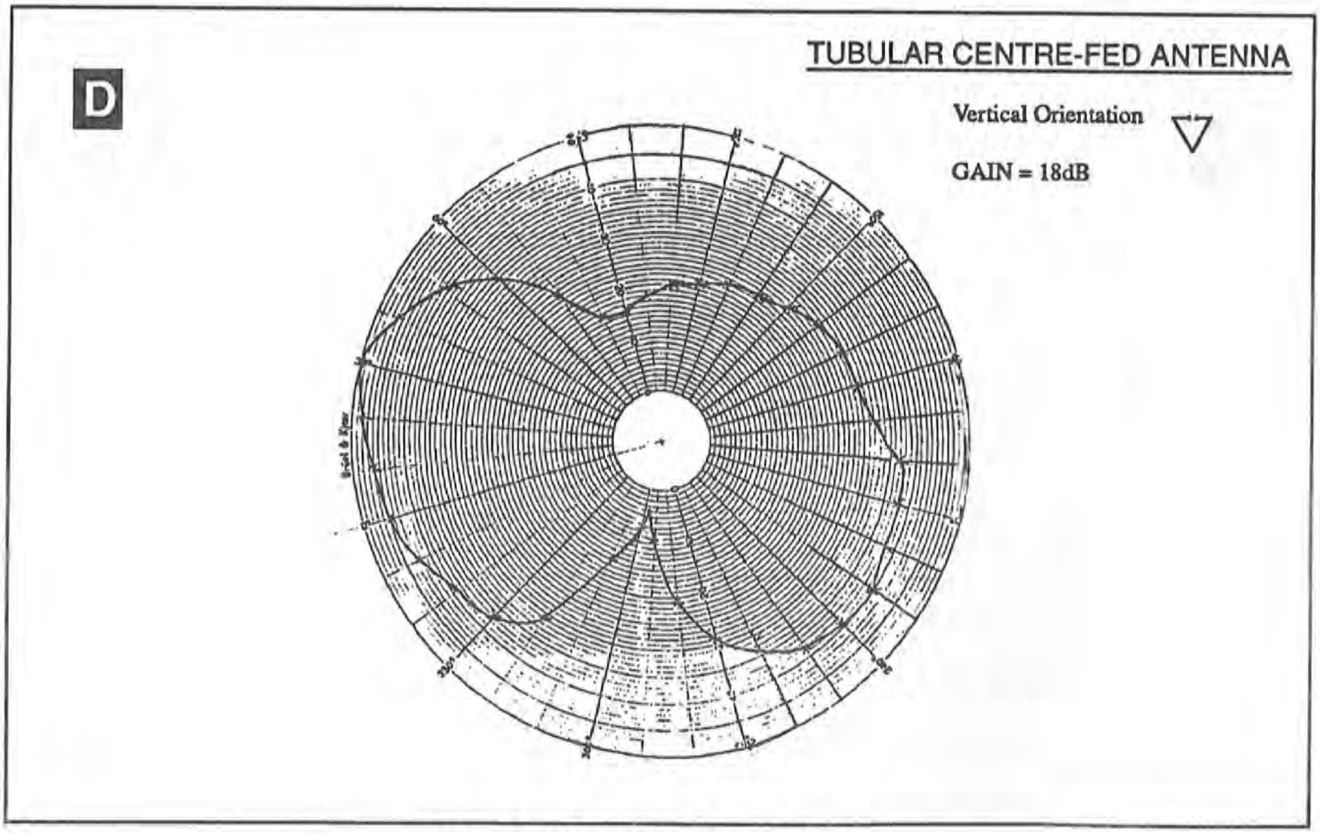

Figure 3 (D): Radiation Pattern Diagram

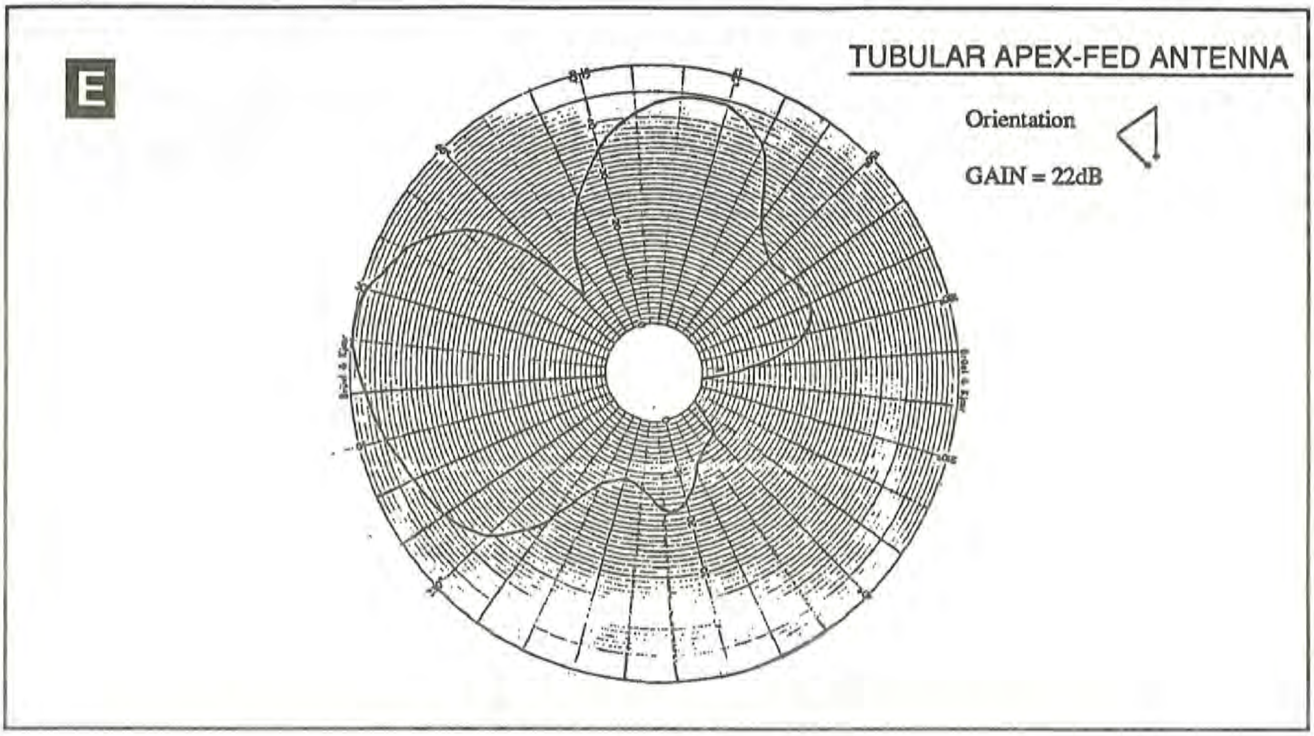

Figure 3 (E): Radiation Pattern Diagram

less frequency dependent than that of a solid conductor (5) delta-loop antenna.

6.0 REFERENCES

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