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Two Antennas For Differential Mesoband Operation

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Abstract

The use of differential high-power sources gives another degree of freedom to antenna design, including two-element arrays. Symmetry considerations are discussed in the context of helical antennas for circular and linear polarizations.

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1. Introduction

In the search for high-power mesoband radiators, a simple and interesting source is the switched oscillator [7]. This produces an approximate damped sinusoid when operated into a high-impedance load (antenna) from a low-characteristic-impedance quarter-wave transmission-line oscillator. There is also a voltage step-up going into the antenna.

Various antennas can be attached to the switched oscillator to give an effective high-power radiator [2]. These include TEM-fed reflectors and (folded) horns. The present paper continues this discussion.

An interesting variant of the switched oscillator is the differential switched oscillator [3-5]. This has the advantage of increasing the voltage output (and the associated power) by doubling the differential versus single-ended voltage for the same current and oscillator characteristic impedance. It is effectively like two oscillators back to back, sharing the same switch. It is appropriate that such a source drive a differential antenna or two antennas symmetrically configured.

One general approach to the antenna problem is to use two antennas, one connected to each oscillator output. These should each present the same load to the oscillator and have the "same" antenna gain. This can be achieved by the use of symmetry considerations in the oscillator/antenna system. Such symmetry can utilize the point symmetry groups (rotation and reflection) [11]. Except for symmetry transformations, the two antennas are then identical.

2. Positioning of Two Antennas

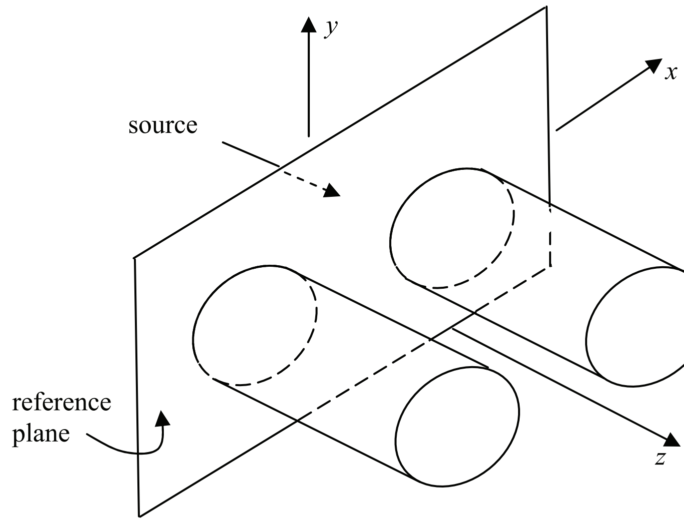
Looking ahead to potential interference from nearby earth, there are two positions of the antennas to consider as indicated in Fig. 2.1. As with double-barrel shotguns we can have side-by-side, or over-and-under antennas. Here the antennas are indicated symbolically by two circular cylindrical antenna volumes. There is a reference plane (which may or may not be a conductor) perpendicular to the *z* axis (direction of propagation) in the *x, y* plane. The source (differential) is assumed to be behind the reference plane.

Neglecting the earth location for the moment, we see that we can regard Fig. 2.1B as a $\pm\pi/2$ $(\pm 90^\circ)$ rotation of Fig. 2.1A. Each of these configurations is assumed to have either rotation (C_2) symmetry in the sense that rotation by π (180°) leaves the configuration invariant, or reflection symmetry (R_x or R_y) so that the *yz* or *xz* planes are planes of symmetry [11]. If both such planes are symmetry planes then, in addition, it has C_2 symmetry giving C_{2a} symmetry.

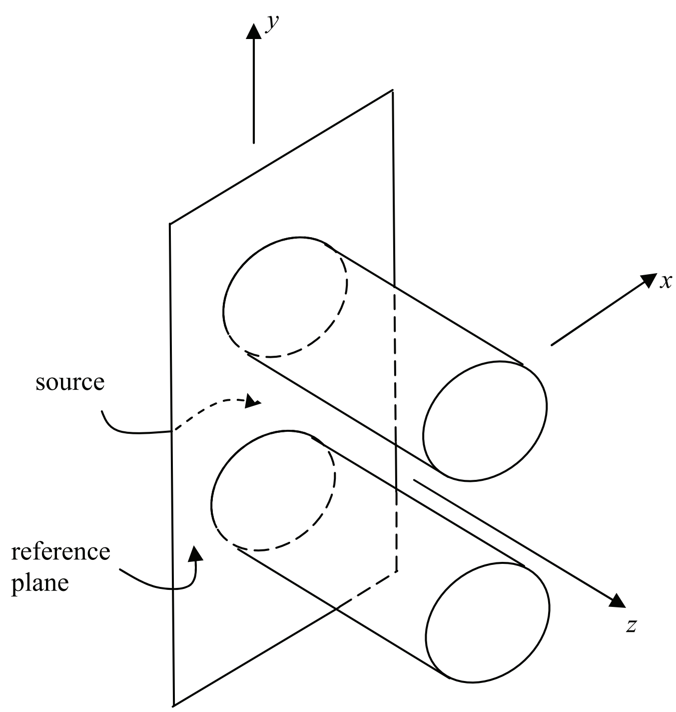
There is a general antenna-pattern consideration as indicated in Fig. 2.2. Taking the over-and-under configuration for illustration, note that the pattern is in general broader for side-by-side as compared to up-and-down. This is due to the greater side-by-side confinement of the antenna array (two elements). By rotation of this configuration by $\pm\pi/2$ to that of Fig. 2.1A we merely rotate the pattern, giving a broad vertical pattern and a (relatively) narrow horizontal pattern. So which configuration in Fig. 2.1 one chooses depends on which coverage one wishes to give over the volume (or cross-section on a plane of constant *z*) the target occupies.

Now consider the influence of a nearby earth surface.. In Fig. 2.3 we have the two antenna configurations near an earth surface which we take as a plane of constant *y*. The side-by-side configuration in Fig. 2.3A has the advantage given by the simultaneous arrival of the ground bounces from the two antennas arriving at the target (center) simultaneously. In this case the $x = 0$ plane can be a symmetry plane provided the antenna array also has R_x symmetry. In this case we can have vertical or horizontal polarization (on the $x = 0$ plane). For vertical polarization we can take advantage of a Brewster angle at the ground surface to reduce the amplitude of the wave reflected to the target [1, 6]. Unfortunately, horizontal polarization has no such Brewster angle.

The over-and-under configuration in Fig. 2.3B also can have R_x symmetry in the presence of the earth surface. However, this suffers the disadvantage of having the ground bounce from the two antennas arrive at the target center at different times. We still can have an approximate Brewster effect for vertical polarization to reduce the ground reflection.



A. Side by side



B. Over and under

Fig. 2.1 Two Configuration for a Two-Element Antenna Array

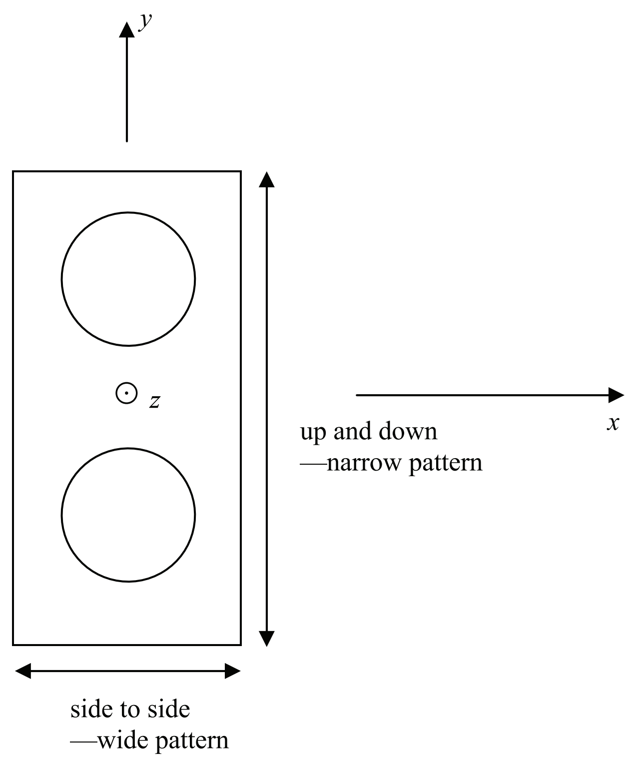
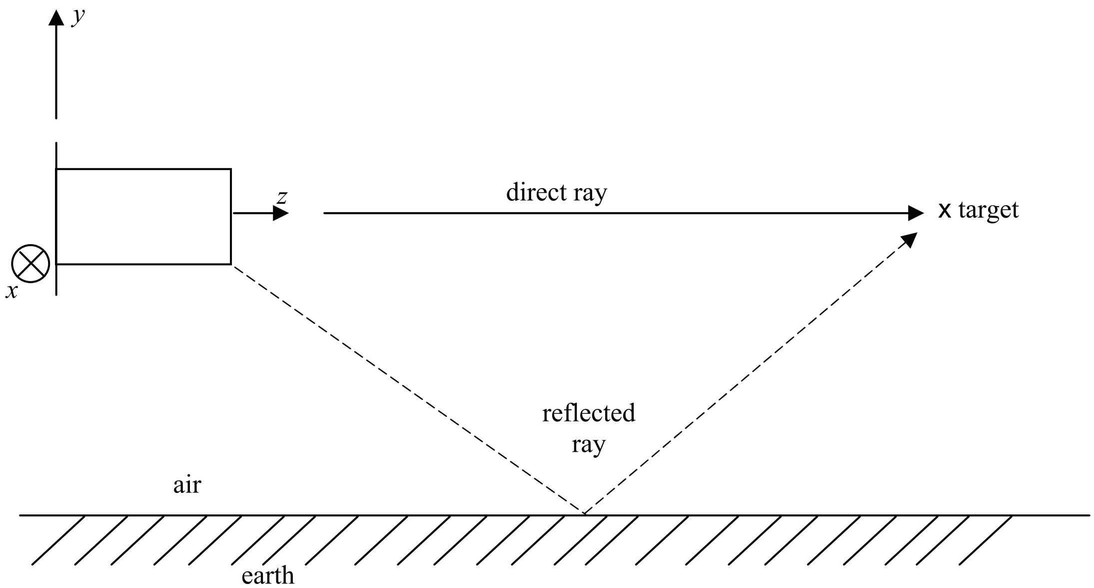
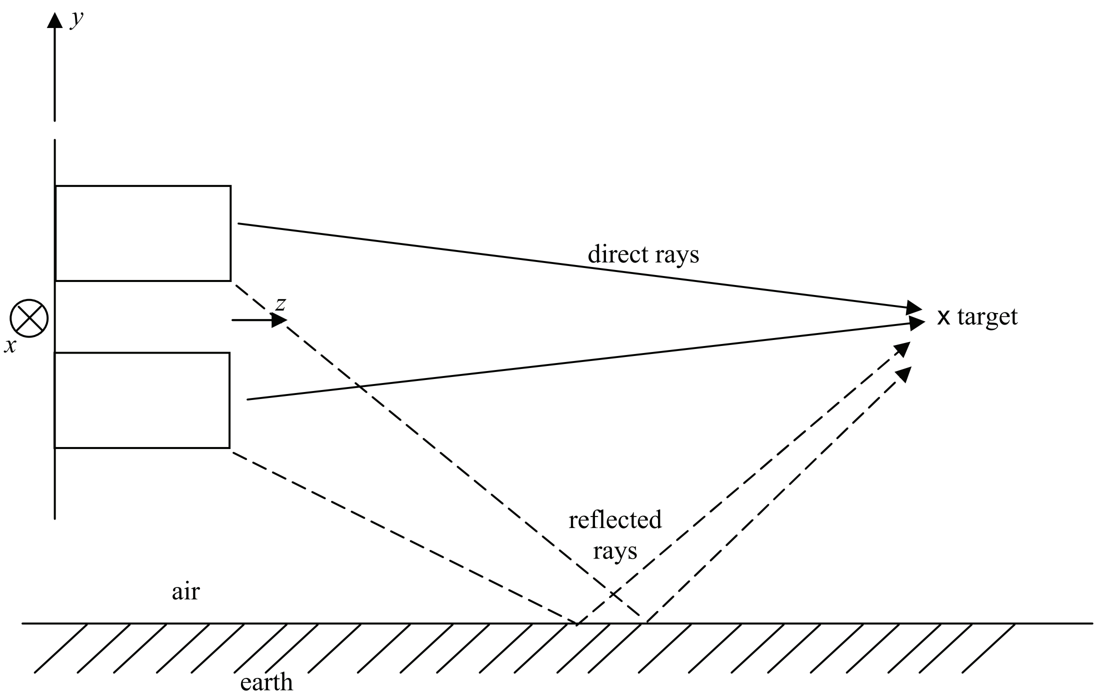


Fig. 2.2 Pattern Considerations for Two Antennas



A. Side by side



B. Over and under

Fig. 2.3 Ground Reflection for Two Antennas

In a test range one can minimize the ground-bounce effect by choice of the ground topography. As indicated in Fig. 2.4 we can have a “canyon” (arroyo) between the antenna array and target. This can significantly lengthen the delay of the ground bounce after the signal on the direct path. Furthermore, by contouring the ground topography we can have the ray reflecting to the target, incident at angle ψ, on the ground surface at the Brewster angle given by

$$\psi = \psi_B = \arctan\left(\varepsilon_r\right)$$
$$\varepsilon_r = \text{relative dielectric constant of ground} \qquad (2.1)$$

This applies only to vertical polarization.

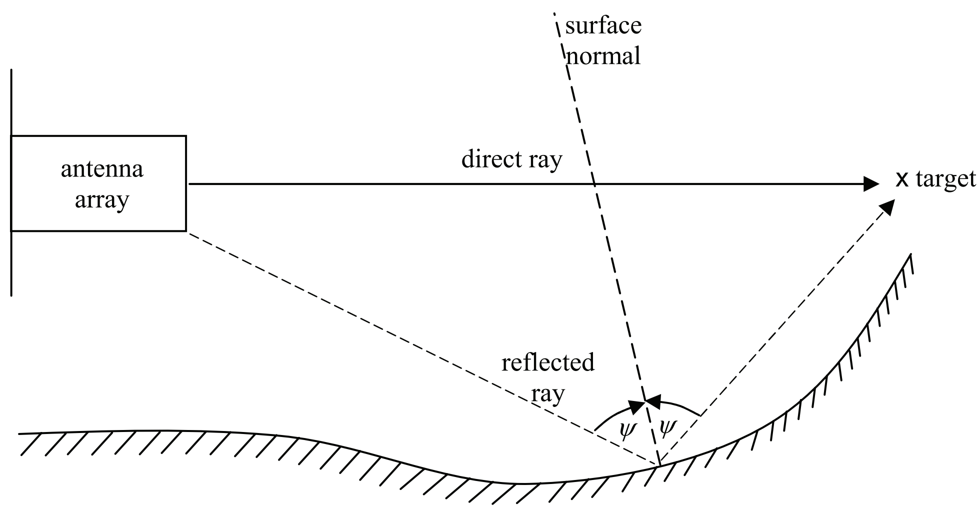


Fig. 2.4 Reduction of Ground Effect

3. Two Helical Antennas

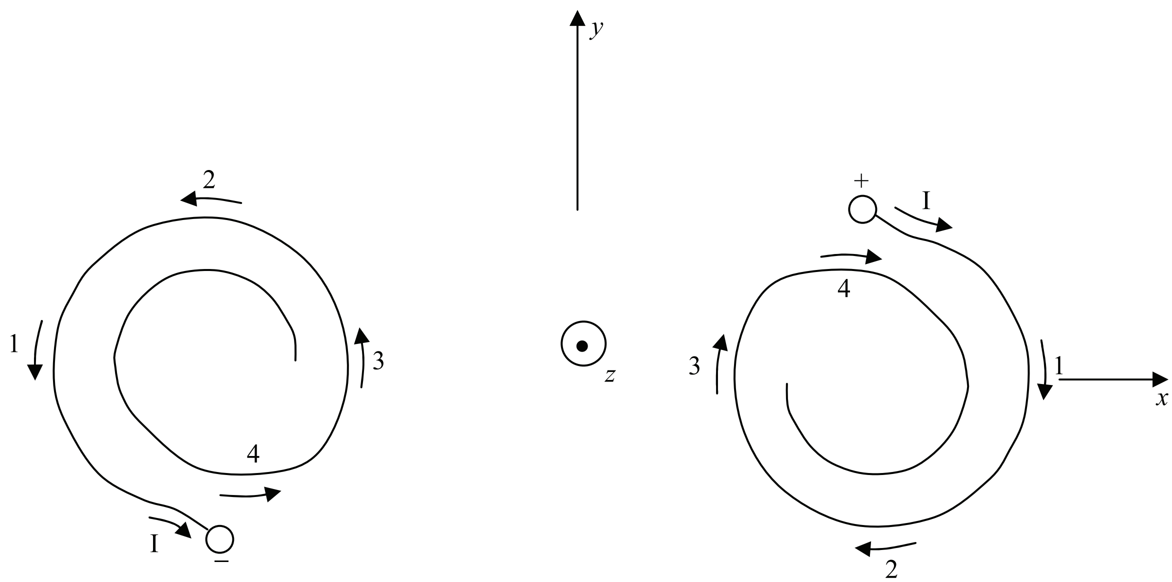
There is some interest in possible use of helical antennas for mesoband sources [8, 9]. Here we explore the possible use of pairs of helical antennas combined with a differential source such as a switched oscillator. Note that the switched oscillator, producing an approximate damped sine wave, can have its center frequency chosen to maximize the response of the helical antennas by placing the oscillator frequency in the center of the axial mode of radiation of each helix [10].

Consider the configurations in Fig. 3.1. Here the helices are wound with the same pitch (handedness). Rotation around the z axis by π replicates the geometry giving C_2 symmetry in both cases. The helices are schematically indicated coming from the source connections on the reference plane ($z = 0$), out of the plane toward the target. The examples are for left-handed helices radiating left-handed circular polarization on the z axis. We can understand this by considering a current I leaving the positive terminal and entering the negative terminal. The numbers 1 to 4 indicate the current along the helix at progressively increasing times. At time 1 the two currents are parallel, and similarly for time 2, etc. The two examples indicate that the source connections can be either outside or inside the circular cylinder defined by the helix, while still retaining the C_2 symmetry.

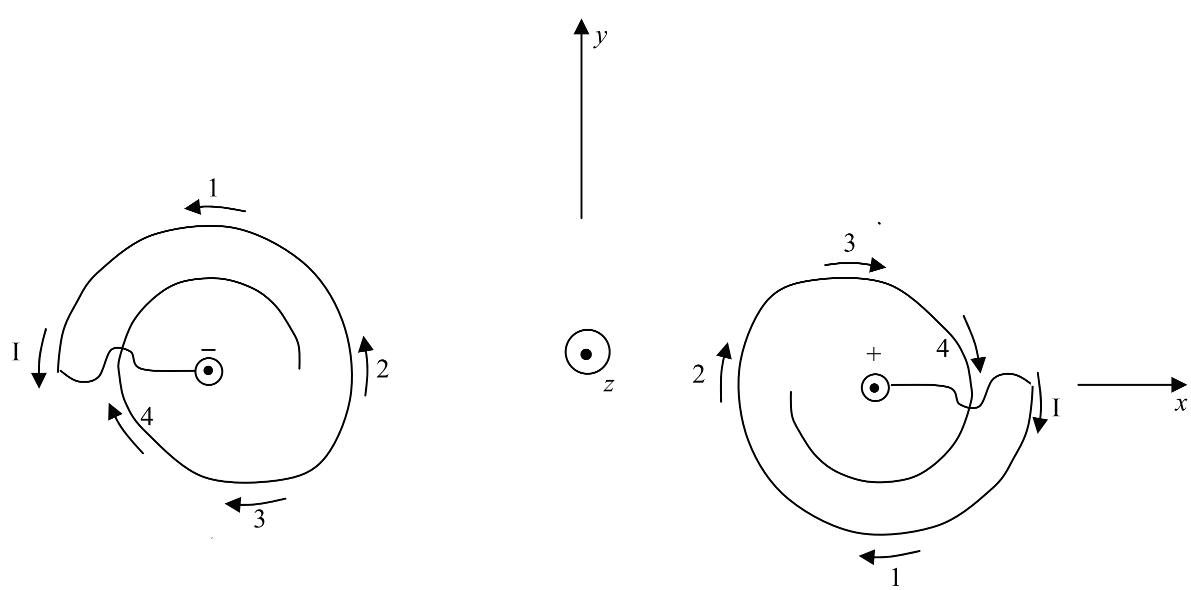
In Fig. 3.2 we have configurations for linear polarization. In this case the two helical antennas have opposite pitch (handedness) to separately radiate opposite circular polarizations. Fig. 3.2A gives an example for horizontal polarization (on the $x = 0$ plane). The configuration has R_x symmetry (reflection through the $x = 0$ plane). For the successive times labeled 1 to 4 for progressive positions along the helix (advancing in z coordinate) we find odd-numbered currents ($\pm$ vertical, antiparallel) with cancelling, radiation, and even-numbered currents (horizontal, parallel) with adding (reinforcing) radiation.

Figure 3.2B shows an example for vertical polarization. In this case (with differential drive) some symmetry is lost due to the additional rotation of one of the helices (including feed) by π. This makes the odd-numbered current add radiation, while the even-numbered ones subtract. If we were using the common mode (both source outputs of the same sign) then the configuration in Fig. 3.2A would give vertical polarization while preserving R_x symmetry.

Figures 3.1 and 3.2 illustrate a side-by-side antenna array. By rotation by $\pm\pi/2$ these are converted to the over-and-under configuration. The circular polarization in Fig. 3.1 is unchanged. The linear polarizations in Fig. 3.2 have the role of horizontal and vertical polarizations interchange on such rotation.

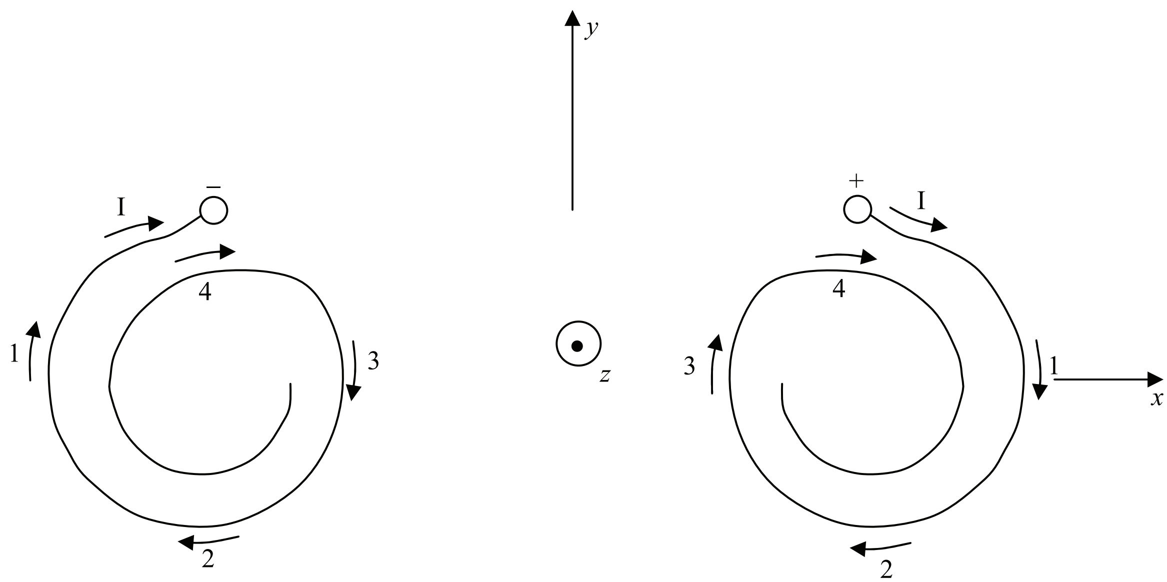


A. Source feeds outside helix cylinder

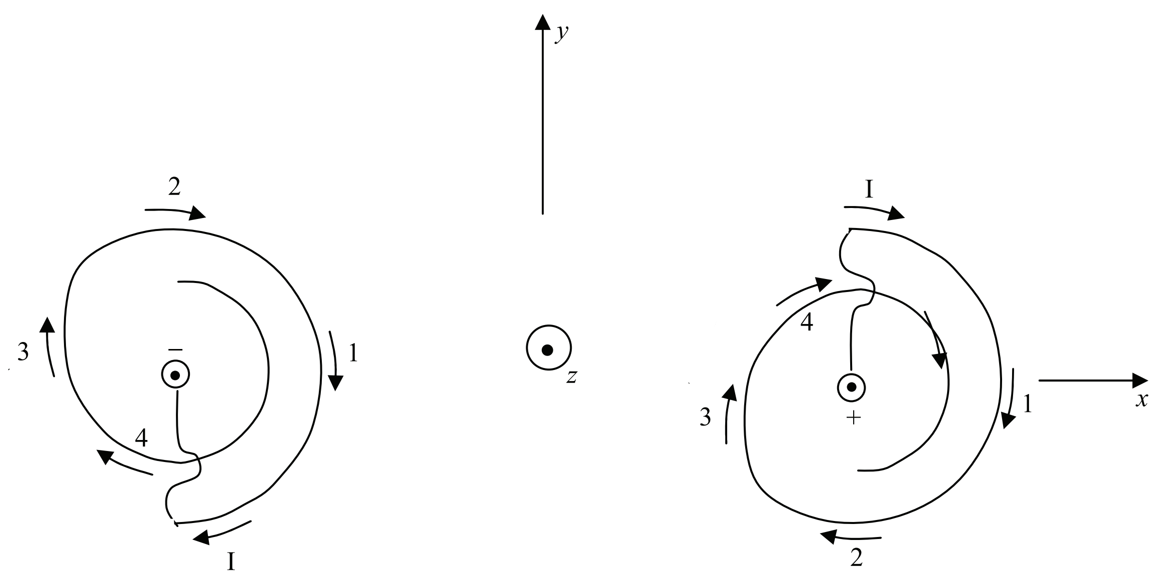


B. Source feeds inside helix cylinder

Fig. 3.1 Identical Helical Antennas for Circular Polarization with Differential Source:
Same Pitch (Handedness) (Helices Are Coming Out of the Page.)



A. Source feeds outside helix cylinder (horizontal polarization)



B. Source feeds outside helix cylinder (vertical polarization)

Fig. 3.2 Counterwound Helical Antennas for Linear Polarization with Differential Source: Opposite Pitch (Handedness) (Helices Are Coming Out of the Page.)

4. Concluding Remarks

Differential sources can then be used with two-element antenna arrays, thereby utilizing an advantage of a differential switched oscillator for mesoband high-power radiation. Here we have considered symmetrical antenna arrays (two elements). While helical antennas have some interest for mesoband radiation, one need not limit ones consideration to this type of antenna.

Other less symmetrical configurations are also possible. For example, for helical antennas one can displace one of a pair of counterwound antennas an appropriate fraction of a wavelength to achieve a linear polarization with arbitrary (or even variable) polarization angle.

References

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