Bioelectric Notes
Note 4
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Tripol Junction for Combining Exposure of Targets to Three Independent Electromagnetic Waveforms with Three Mutually Perpendicular Polarizations

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Abstract

This paper considers the use of symmetry to obtain an illumination procedure for three independent electromagnetic waves interacting with a test object. The three polarizations are mutually orthogonal (tripol). The waves propagate in the differential modes of three TEM transmission lines.

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1. Introduction

In order to expose biological samples to more than one electromagnetic environment simultaneously, or at nearly the same time, one can utilize electromagnetic polarization and direction of incidence for the various environments. By appropriate use of orthogonality, the various environments can be independently controlled without significant scattering of one environment into another.

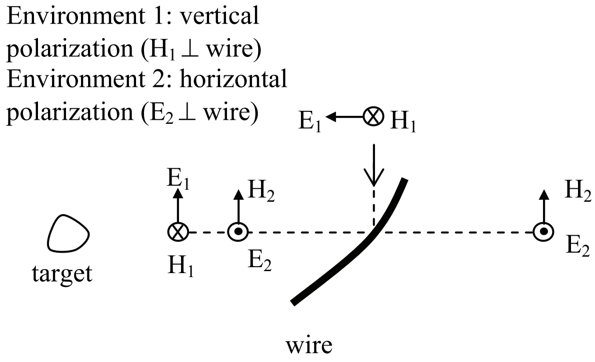
As an example[1], consider the configuration in Fig. 1.1. In this case, we have two electromagnetic environments, which are crosspolarized to each other, but are incident on a target (perhaps biological) with the same directions of incidence. The “trick,” in this case, is the use of a wire grid which reflects a vertically polarized field (wires “parallel” to $\vec{E}_1$) while being transparent to a horizontally polarized field (wires perpendicular to $\vec{E}_2$).

This is an example of a radiating system in which the various electromagnetic environments are dominated by frequencies with short wavelengths. The wire grid can take the form of a shaped (e.g., paraboloidal) reflector to concentrate (i.e., focus) the vertically polarized beam on the target. Similarly, the horizontally polarized beam can be concentrated on the target by use of concave reflectors and or lenses.

As an example, one of the two beams might be sinusoidal for heating the target, while the other beam might be a fast, intense pulse for inducing special biological effects (electroporation, apoptosis) in the target. Of course, some number of such dually polarized beams can all be pointed at the same target.

The present paper explores another configuration, with a high degree of symmetry, utilizing transmission-line geometries to independently control three electromagnetic environments incident on a test sample with three mutually orthogonal directions of incidence and polarizations.

A. Side view



B. Top View

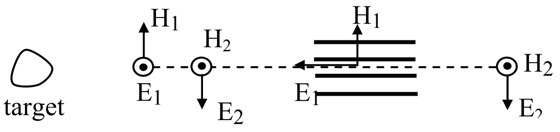


Fig. 1.1. Use of Cross Polarization with Same Direction of Incidence to Expose Targets to Two Different Electromagnetic Environments

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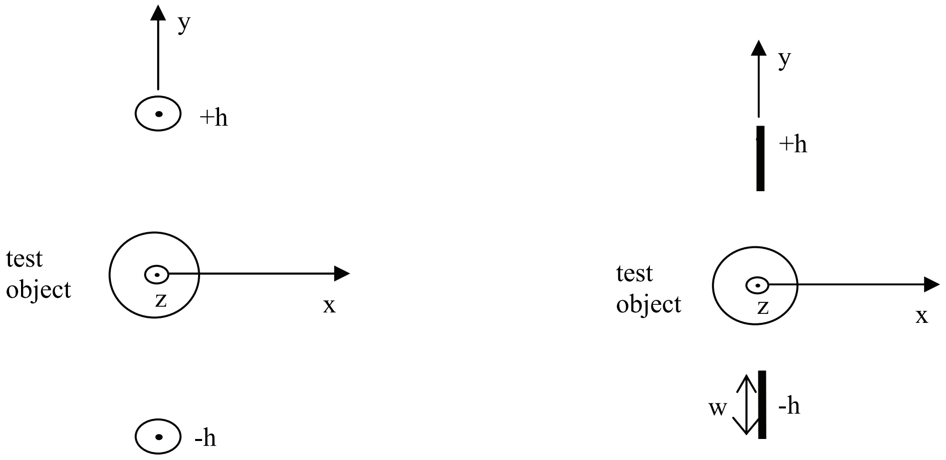
[1] Patent applied.

2. TEM Transmission Lines With Two symmetry Planes Parallel to Propagation Direction

Consider now a two-conductor TEM transmission line as illustrated in Fig. 2.1. Let there be two symmetry planes, xz, with respect to which the fields are antisymmetric [2], and yz with respect to which the fields are symmetric [2]. For simplicity, one might have two identical cylindrical wires [1], as in Fig. 2.1A, or two identical (perfectly conducting) strips on the yz plane as in Fig. 2.1B. The strips have the advantage that other fields, polarized in the x direction (to be discussed later), have minimal interaction with the strips. However, wires of small diameter will have only a small interaction with such fields.

Here we are concerned with the differential mode ($\pm V$, $\pm I$) on the 2-wire system. The common mode is avoided as much as possible, being suppressed when necessary.

Such a TEM transmission line has translation symmetry (continuous) with respect to the z axis. It also has reflection symmetry with respect to the xy plane. As we shall see, when we combine three of these, the translation symmetry is lost, but the reflection symmetry (with respect to the xy plane) is retained. For completeness we should also like the test object to have the same three symmetry planes (such as of a spheroid, elliptic cylinder of finite length, etc.).



A. Rods (wires)

B. Flat Strips

Fig. 2.1 Cross Section of Special TEM Transmission Lines With Two Symmetry Planes

3. Three Intersecting Differential-Mode TEM Transmission Lines

Carrying the discussion further, now consider three such transmission lines propagating at right angles to each other, intersecting (with no electrical contact) around the coordinate origin as in Fig. 3.1. Here we see how a wave (differential) propagating in the $\pm x$ direction has negligible interaction with the transmission-line conductors aligned in the $\pm y$ direction. In the case of the $\pm z$-directed transmission line, the x-wave fields do induce a *common-mode signal* in the z transmission line. So it is important that the influence of this mode be suppressed by maintenance of symmetry in the transmission line and its loading impedances. One can also envision bifilar chokes (or special transformers) which place a large impedance into the common mode, while placing negligible impedance in the differential mode.

Of course, three different electromagnetic waveforms (and amplitudes) can be propagated in a non-interacting manner on such a structure with three orthogonal polarization (tripol). For completeness, the test object should also have the same three symmetry planes to avoid coupling between two (or three) differential modes.

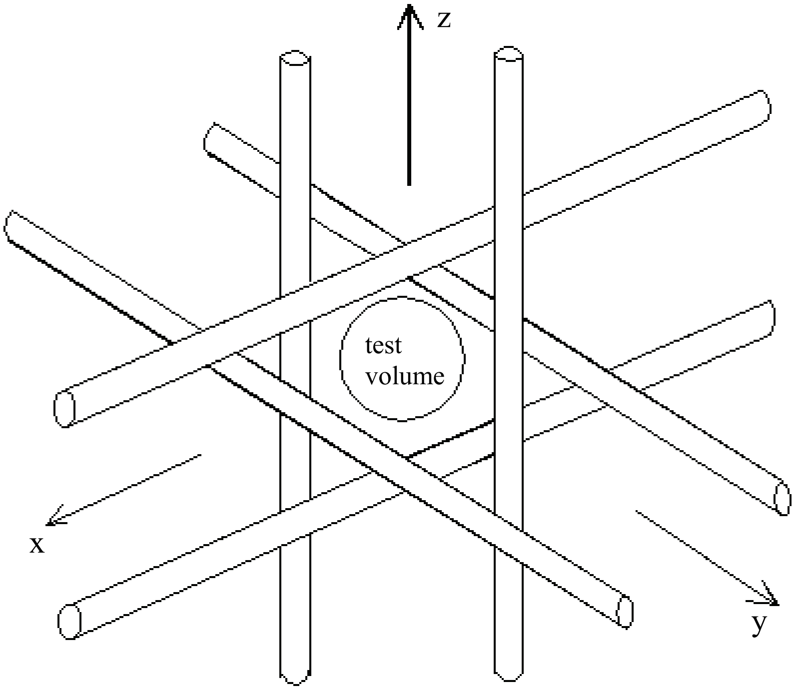


Fig. 3.1 Three Intersecting Symmetrical Differential-Mode TEM Transmission Lines

4. Symmetry Groups

Now consider the point symmetry group describing the transmission–line structure [2]. There are various ways to look at this by considering the various rotation and reflections which leave the structure unchanged.

A. Rotations (proper rotations)

There are three C_2 rotation axes (rotation by π) around each of the 3 coordinate axes. Twice application of each of these returns to the identity. This describes dihedral D_2 symmetry. Note that in these rotations a direction of propagation is reversed on two of the transmission lines (as well as the polarities on two of the lines).

B. Compound Rotations

Rotate by $\pi/2$ (90°) about a coordinate axis (say x), and then by the same angle about another coordinate axis (say y), again leaving the structure unchanged. There are two ways to make the second move, given the first, for a total of 6 group elements.

C. Reflections

There are three reflection symmetry planes (the three coordinate planes) for three group elements. (Two reflections gives a proper rotation. Three gives an inversion. All are symmetries here.) The rotation axes being in the symmetry planes, one can consider this as D_{2a} symmetry.

D. Combinations

As we can see, this structure has a high degree of symmetry. The previous symmetry operations can be combined in any order to leave the geometry invariant.

5. Test Volume

The test volume is centered on the coordinate origin (Fig. 3.1). For minimum coupling of the differential mode on one transmission line to that on another, it is necessary that the test object (shape, permittivity, etc.) have symmetries consistent with those in the previous section. In particular, one can make the three coordinate planes as reflection symmetry planes. Noting that two reflections can give a rotation (a proper rotation) [2], this gives the symmetries of a cube or octahedron (group O [2]).

6. Concluding Remarks

Symmetry is then a powerful concept for organizing the interaction of various electromgnetic waves with some test object. The symmetry applies to both the illuminator and the test object (e.g., biological sample). The present configuration allows interaction of the test object with three independent waveforms (amplitudes, frequencies, pulse shapes) with three orthogonal polarizations. From an application point of view, one might have a CW waveform heating the target, the second wave might be a narrow intense pulse for inducing biological effects, and the third might be used for diagnostic purposes.

References

1. C.E. Baum, Impedances and Field Distributions for Symmetrical Two-Wire and Four-Wire Transmission Line Simulators, Sensor and Simulation Note 27, October, 1966.

2. C.E. Baum and H.N. Kritikos, "Symmetry in Electromagnetics," Ch. 1, pp. 1-90, in C.E. Baum and H.N. Kritikos (eds.), *Electromagnetic Symmetry*, Taylor & Francis, 1995.