Sensor and Simulation Notes

Note 540

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Some Propagation Geometries for Correlation Measurements of Antenna Switching Spread

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Abstract

This paper extends the design principle of symmetry to the various pieces of a system for focusing waves from multiple sources onto a single receiving antenna. An additional technique involving polarization is also discussed.

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1. Introduction

A recent paper [2] discusses the use of symmetry to measure the synchronization of switched oscillators/ antennas. The spread of the switching times (say 90% within a given time window (the spread)) away from their desired triggering (closure) time, allowing for propagation-path delays, needs to be small compared to a radian period (period/2π) of the oscillation. While symmetry plays a key role, there still needs to be appropriate consideration of maximizing (or at least strengthening) the signals reaching the receiver where the signals are summed. For THz frequencies the above problems are especially difficult.

The current paper considers various ways to combine the radiation from various sources, while paying attention to the radiation beams.

2. Antennas and Reflectors, Side by Side, and Over and Under

As discussed in [2 (Fig. 2.1)] we can have up to four sources (oscillators/antennas) each with two symmetry planes (parallel to the *xy* and *yz* planes) and symmetrically located with respect to these planes as in Fig. 2.1. Retaining these symmetries each antenna can have a reflecting conducting sheet [1] to direct the four waves into four paraboloidal reflectors. This gives four parallel beams with the same polarization (say *z* direction, but could also be *x* direction).

In turn each of these beams is concentrated on the receiver by a focusing reflector. These four reflectors should also exhibit symmetry with respect to the *xy* and *yz* planes. The receiver itself has both *xy* and *yz* symmetry planes. Note that Fig. 2.1 is a top view (viewing in the –*z* direction) so that sources and reflectors 3 and 4 are directly under numbers 2 and 1, respectively.

There are variations on this kind of symmetry:

1. Eliminate the focusing reflectors. Cant the sources and parabolic reflectors to radiate directly at the receiver. Modify each parabolic reflector to be a prolate spheroidal reflector with first focus at the source antenna and second focus at the receiver [4]. Maintain the *xy* and *yz* symmetry planes.
2. Replace the reflectors with lenses (low-loss dielectric), perhaps with quarter-wave coatings. The sources then can produce parallel beams by propagating the source waves through them. These beams can be directly focused on the reflectors, or can be made parallel beams which in turn are focused on the receiver after bending the beams. Maintain the *xy* and *yz* symmetry planes.
3. Combine various features from all the above.

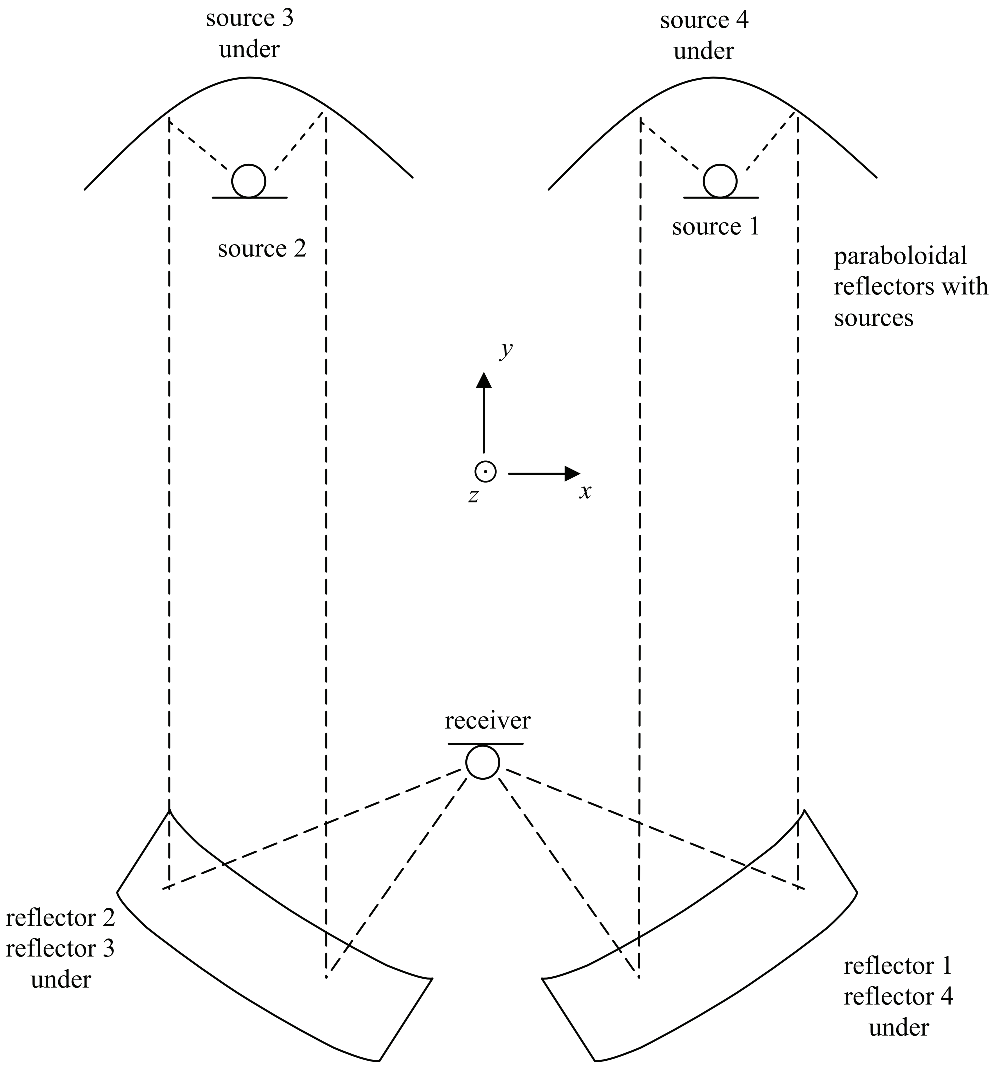


Fig. 2.1 Four Sources With Beams Symmetrically Directed to Receiver.

3. Sources on Both Sides of Receiver With Three Symmetry Planes

Figure 3.1 shows how one might extend the number of sources to eight, by extension of the symmetry to a third symmetry plane. The receiver should have three symmetry planes. It should be equally sensitive on both sides in such a way that the waves from both sides can add or interfere on the *xz* symmetry plane. This may require special considerations in the receiving element and receiving antenna so that the proper (vector) sum can be achieved over all eight sources. This may require a thin detector element (compared to radian wavelength), or a special antenna bringing the signals from all waves together before being detected.

Previous considerations [2] have shown that, when four sources add all in phase, the energy received in 16 times that of a single source. With eight sources this can be increased, in principle, to 64 times the energy.

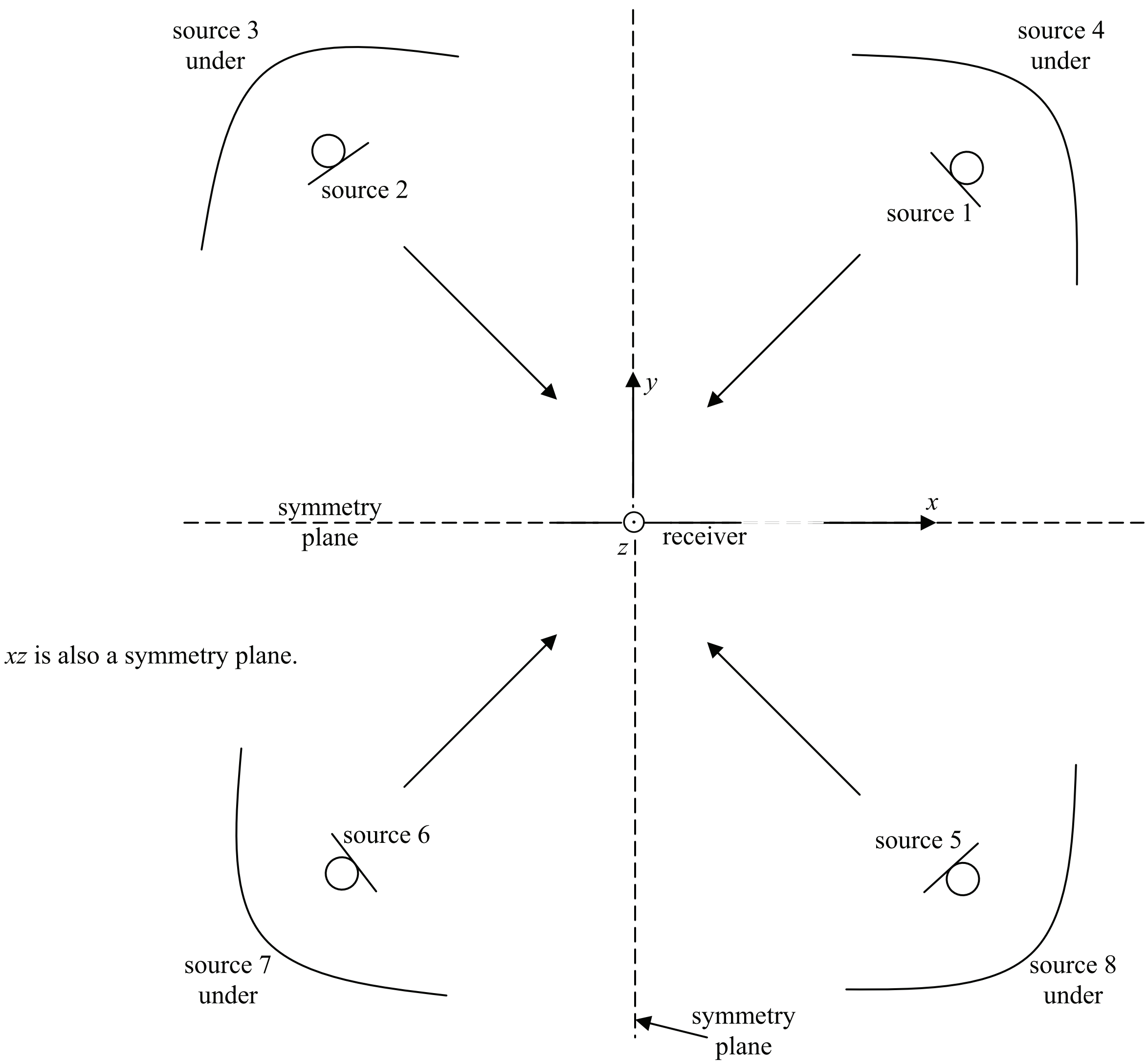


Fig. 3.1 Sources/Antennas Arrayed on Both Sides of Receiver: Three Symmetry Planes, Eight sources.

4. Transmission Through and Reflection From a Polarized Grid

Similar to a technique discussed in [3] we can use a polarizing grid to combine two electromagnetic waves. As in Fig. 4.1A the basic idea is to make two crosspolarized waves by use of a grid. A vertically polarized wave has its electric field perpendicular to the wires and propagates (mostly) through the grid (back wave). A horizontally polarized wave has its magnetic field perpendicular to the grid (side wave) and reflects (mostly) off the grid provided the "wires" are spaced closely together compared to wavelength. The grid is canted so that the side wave can come into the main beam direction (-z direction) from whichever side direction one wishes (not necessarily $\pi/2$ (90°)).

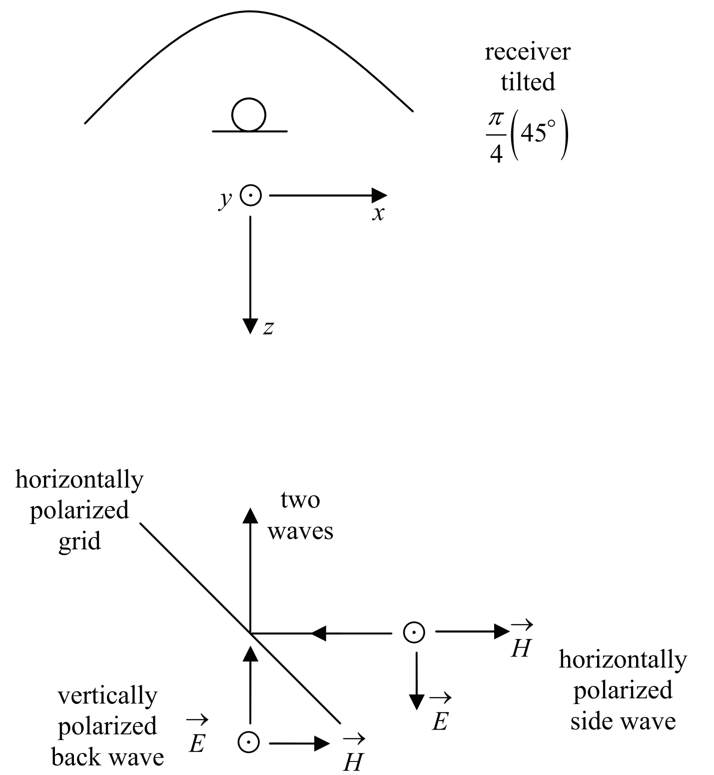
As in Fig. 4.1B we can see two waves impinging on the receiver, while at right angles to each other. To sum these two waves we can use an antenna polarized in the $\vec{1}_a$ direction, where

$$\vec{1}_a = \begin{cases} \pm\frac{1}{\sqrt{2}}\left[\vec{1}_x + \vec{1}_y\right] \\ \text{or} \\ \pm\frac{1}{\sqrt{2}}\left[\vec{1}_x - \vec{1}_y\right] \end{cases} \tag{4.1}$$

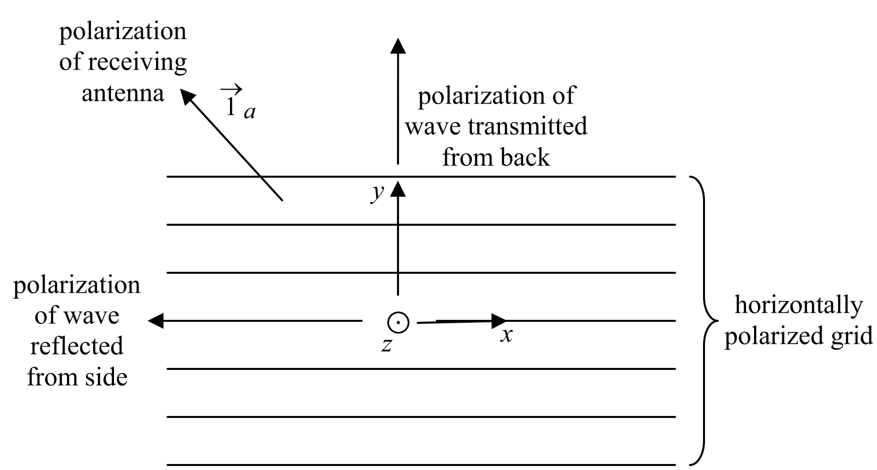
This will take equal amplitude ($2^{-1/2}$ of original field strength) from each wave.

One will need to be careful in this technique to properly match the amplitudes and phases of the vertically polarized back wave, and horizontally polarized side wave. Phases (allowing for perturbation by the grid) can be adjusted by varying propagation path lengths. Amplitudes can be adjusted in various ways by lenses and reflectors to vary the beam sizes. Another approach (for amplitudes) consists of varying $\vec{1}_a$ away from the (4.1) values until a match is reached.

This technique can also be combined with the ones in the previous sections. However, the polarizing grid may be difficult to achieve at THz frequencies. One can envision narrow conductors (wires) deposited on a dielectric, perhaps covered with more dielectric. This will complicate the wave transmission and reflection.



A. Top view



B. View from back toward target

Fig. 4.1 Use of Polarized Grid to Combine Two Waves

5. Concluding Remarks

We can see that there are a variety of techniques that one can use to combine waves from various sources onto a single receiver, extending the results in [2]. These involve symmetry in geometry, reflectors and/or lenses to direct and focus the beams, and use of polarization of the beams. These are basic considerations, but only the start of a design. Many details are still left in the design and construction of the various pieces.

References

1. C. E. Baum, "Some Planar Geometries for Small Antennas With Switched Oscillators for THz Mesoband Radiators", Sensor and Simulation Note 532, May 2008.

2. C. E. Baum, "Use of Symmetry for Measuring the Spread of Switching Times for Extremely-High-Frequency Radiating Sources", Switching Note 34, May 2008.

3. C. E. Baum, S. Altunc, K. H. Schoenbach, and S. Xiao, "Tripol Junction for Combining Exposure of Targets to Three Independent Electromagnetic Waveforms with Three Mutually Perpendicular Polarizations", Bioelectrics Note 4, October 2008.

4. C. E. Baum, "Focal Waveform of a Prolate-Spheroidal Impulse-Radiating Antenna", Radio Science, 11 pp., Vol. 42, No. 6, RS6S27, November-December 2007; also Sensor and Simulation Note 509, February 2006.