Multifocal Bootlace Lens Design Concepts

Reflectors and lenses provide two optical mechanisms to magnify small apertures. They also provide limited scanning of the narrow beams that are produced by the magnified aperture. In both cases, scanning is achieved by switching the feed element location. However, there are a number of basic differences between the two structures. While the reflector system is less complex than the lens, it may occupy more volume for the same features and may suffer from blockage losses. The reflector has a single perfect focal point where secondary radiation has a planar phase front. Other elements in the feed array produce non-planar wave fronts or planar fronts with significant phase variations. The bootlace or Rotman lenses, on the other hand, have three multiple-element radiating structures, and offer more degrees of freedom that help in realizing multiple focal points. The three radiating structures are the feed array, the receiving array on one side of the lens, and the radiating array on the other side of the lens. The traditional bootlace lens is two dimensional, with feed points, receiving, and transmitting arrays all lying on a plane. While this provides for easy strip-line or printed circuit fabrications, there is no physical restriction from extending the formulations to three-dimensional structures.

The degrees of freedom in a bootlace lens include the feed element locations and the transmission line lengths between the receiving and radiating sides of the lens. These allow for choosing a simple planar array surface on the radiating side and for optimizing the parameters to produce multiple perfect focal points with little phase errors for points that fall in between the perfect foci. The optimization process, aiming at increasing the number of focal points and minimizing the phase errors at other points, has produced lens designs with two to five focal points. Some of these are: the 2-dimensional Rotman Lens, with a straight radiating aperture and three perfect focal source points; the Planar McGrath Lens, with straight inner surface as well and two focal points; the Rao Bifocal Lens with two focal points, the Quadrufocal Lens, with four perfect focal points, and the three-dimensional Quintafocal Lens which can scan beams in two dimensions. These lens configurations offer a broadband, high performance alternative to reflector antennas.

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