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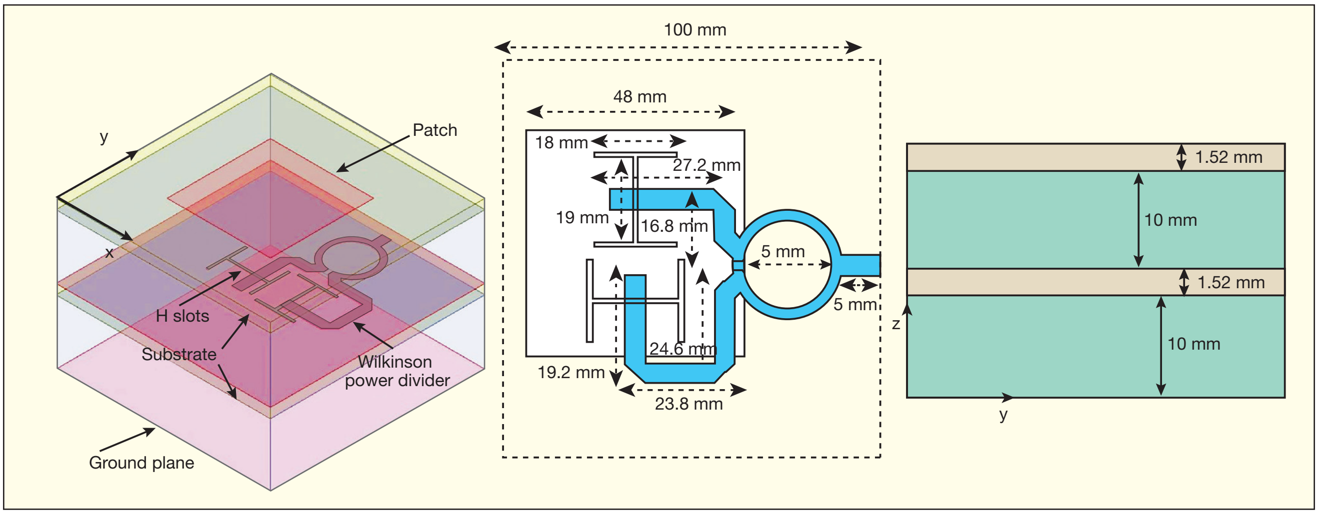
SEQUENTIAL ROTATION

Feeds Microstrip Array

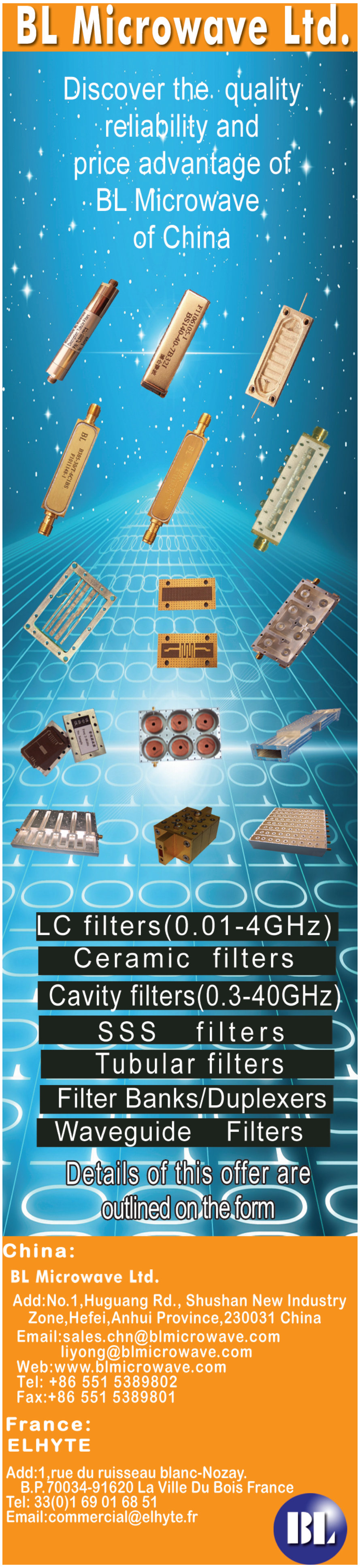
THIS ANTENNA DESIGN APPROACH BUILDS A SIMPLE ARRAY FROM MICROSTRIP ANTENNA ELEMENTS, FORMING A BROADBAND CIRCULARLY POLARIZED WAVE.

MICROSTRIP ANTENNAS offer many benefits, including low profile, light weight, and low cost; they are fairly simple to manufacture and easy to integrate with other planar circuits. Unfortunately, microwave antennas are notoriously narrowband in nature, limiting their use for many applications. A number of approaches have been applied to overcome the inherently narrow bandwidths of microstrip antennas—one dating as far back as 1985.[1] That technique was based on the use of an aperture-coupled feed structure.

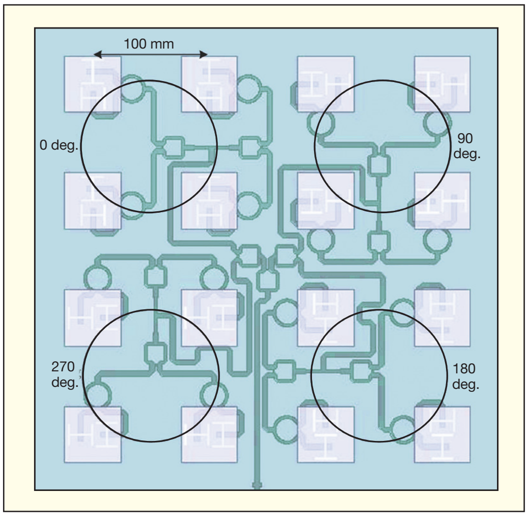
Other attempts have involved different slot shapes in the ground plane of the microstrip antenna,[2] with the result being that the antenna's magnetic (H) slot has larger coupling. The current design incorporates H slots in quadrature, to obtain a wideband circular polarization wave. The H slots are fed by a Wilkinson power divider, using its 90-deg. phase-shifted outputs with the same amplitudes.



1. These different views show (l-r) the wideband microstrip antenna geometry, the top view of the antenna element, and the side view of the antenna element.



In recent years, various microstrip antenna arrays have been designed using a sequential rotation technique, with the aim of improving polarization purity, impedance matching, and pattern symmetry across wider bandwidths.[3-12] These designs include the use of linearly polarized elements,[3-5] circularly polarized microstrip elements,[6-10] and feed networks incorporating serial or parallel feeds.[11,12] Such approaches can improve the circularly polarized bandwidth, but tend not to impact the axial ratio bandwidth.



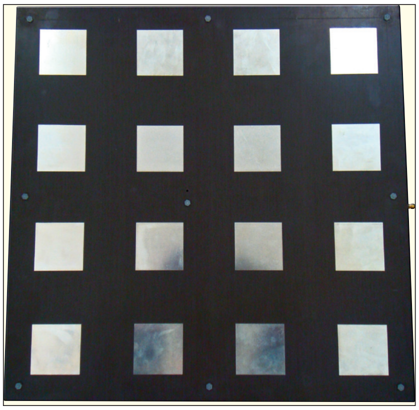
2. The microstrip array antenna, with each element offset by 90 deg., is depicted in this layout.

For example, the best results registered for axial ratio bandwidth by these researchers was 45%. In this case, a wideband aperture-coupled microstrip antenna was employed as the basic resonant element, although the element is also referred to as an aperture-coupled microstrip antenna in the literature.[9] It adopts a branch-line coupler to feed two orthogonally located feeds quadrature to each other. The coupler has a extra load port and a parasitic patch to improve the impedance bandwidth but with a penalty of increased height.

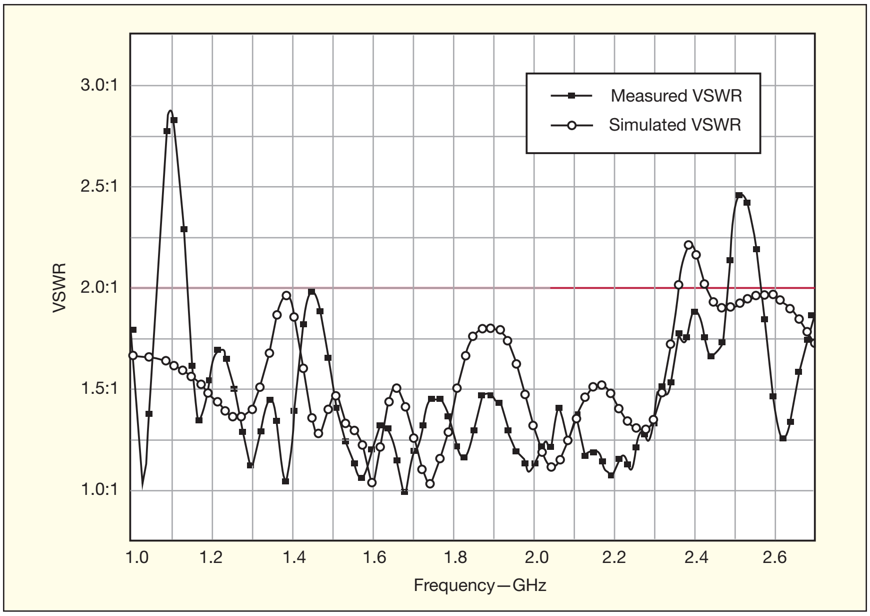
As an alternative antenna design approach, a 4 × 4 circularly polarized microstrip antenna array was designed using a sequentially rotated microstrip line to excite the H-slot aperture-coupled microstrip antenna. Wilkinson power dividers, which provide wide bandwidth and high isolation, provide the signal power division for the feed network. Hence, this microstrip antenna array achieves high gain and better wideband circular polarization characteristic than the design in ref. 9.

Figure 1 shows the antenna element configuration. It consists of three layers: The upper layer is a square patch which serves as radiator; the middle layer is the ground plane with H slots in quadrature; and the lower layer is a feed network with a Wilkinson power divider featuring two quadrature output arms, supplying a 90-deg. phase shift to obtain a circularly polarized wave. After mass simulation and optimization using version Ansoft HFSS10.0 of the High-Frequency Structure Simulator (HFSS) finite-element computer-aided-engineering (CAE) simulation software from Ansys (www.ansys.com), the ultimate parameters used for the microstrip antenna array design are indicated in **Fig. 1**.

To obtain high gain and good wideband circular polarization performance, the H-slot aperture-coupled microstrip antenna was used as the basic element in an array. A four-element microstrip antenna was created as a subarray without any sequential rotation, and a quartet of four-element subarrays



3. The fabricated broadband microstrip antenna is shown in this photograph.



4. These plots show simulated and measured VSWR versus frequency for the wideband microstrip antenna.

were then fed with a sequential rotation technique using a 90-deg phase shift between each other (as shown in **Fig. 2**). The distance between adjacent elements is 100 mm (0.67λ_0, where λ_0 is the free-space wavelength of the center frequency of interest).

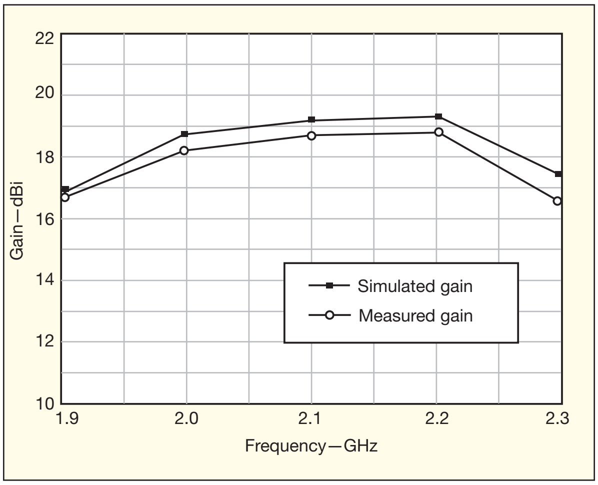
For the sequentially rotated feed network, the feeding point to the full array is at the edge of the substrate. This is because the distance between the reflection board and the feed layer is just 10 mm. This is not easy for an SMA connection with probe feeding, so this structure will exhibit a little higher conductor loss due to the added microstrip line.

The microstrip line feeds of the patch antenna array are arranged for a 90-deg. phase shift with respect to the neighbor with same width of 50 Ω in spite of the 100-Ω microstrip line used in the Wilkinson power divider. The feed network should be carefully designed to confirm that the phase shift sent to each element is at the specific, required values. For example, the corner number should be reduced and the distance between the feed lines should be more adequate for reduced coupling.

To validate the authors' design approach, a prototype of a 16-element aperture-coupled microstrip antenna was fabricated and tested **(Fig. 3)**. The VSWR was simulated with commercial CAE software, and measured with the assistance of a model E8363B vector network analyzer (VNA) from Agilent Technologies (www.agilent.com). The simulated and measured VSWR results are shown in **Fig. 4**.

The design shows an impressive bandwidth of 74% from 1.13 to 2.48 GHz with measured VSWR of less than 2.0:1 across the bandwidth. The measured bandwidth shows a slight shift towards higher frequencies than the simulated performance, likely due to measurement errors and fabrication inconsistencies. **Figure 5** shows simulated and measured gain versus frequency, with gain of more than 16.6 dBi over an 18.9% bandwidth from 1.92 to 2.32 GHz, and peak gain of 18.7 dBi at the center frequency. **Figure 6** shows the simulated and measured axial ratio, indicating a 3-dB bandwidth of 57% from 1.5 to 2.7 GHz.

In short, a wideband and high-gain, circularly polarized, aperture-coupled microstrip antenna array is presented



5. These plots show simulated and measured gain versus frequency for the wideband microstrip antenna.

here. A 16-element array was obtained by adopting a sequential rotation feeding technique to achieve a wider circular polarization bandwidth than normally possible, using the H-slot aperture-coupled microstrip antenna as an element in the array.

The impedance bandwidth (for a VSWR of less than 2.0:1) and 3-dB axial-ratio bandwidth register 74% and 57%, respectively. The microstrip array achieves 18.7-dBi gain at the center of the band and represents a viable candidate for a number of wideband communications applications. MWRF

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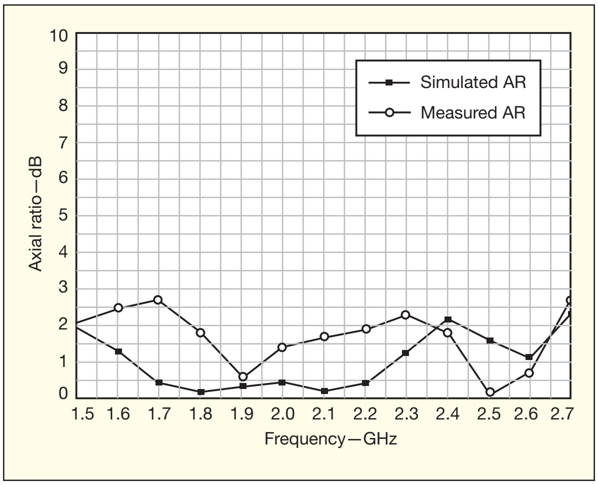

6. These plots show simulated and measured axial ratio (AR) as functions of frequency from 1.5 to 2.7 GHz for the wideband microstrip antenna.