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Planar Microstrip Yagi Array with Notched Parasitic Elements

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Abstract: The design and radiation characteristics of a planar microstrip Yagi array with notched parasitic elements are presented. Results indicate that a directional beam 45° from the broadside direction with a gain over 7 dB can be achieved. Good agreements were observed between experimental and analytical results.

Introduction: A planar microstrip Yagi array consisting of a single fed patch antenna element, a single parasitic reflector element and two parasitic director elements was introduced in 1991 for mobile satellite vehicle application [1]. Unlike the conventional Yagi dipole array, which is used primarily for gain enhancement [2], this array is designed to produce a directional beam within the angular region between 20° and 60° elevation. The beam is steered away from its broadside direction through mutual coupling of electromagnetic energy from the driven patch to the parasitic patches. In order to produce a beam in a specified direction, proper phase settings of all the parasitic elements, both the reflector and the directors, are required so that radiation from each element is added up coherently. In the case of the Yagi array reported in [1], correct phase delay to each antenna element was achieved by proper variation of the element size and element spacing. It has been reported that proper phase delay can also be obtained by introducing notches or slots in an antenna element [3]. A slot cut on a microstrip antenna cause the surface current to flow around the slot resulting in a longer current flow path, a decrease in the resonant frequency, and consequently, a phase delay. In this work, we study both analytically and experimentally the scanning capability of a planar printed microstrip Yagi array using notched elements as reflector and directors. The array is designed to generate a 45° beam which is required for mobile communications.

Array Design: A schematic of the proposed Yagi array is shown in Fig. 1. The array consisting of identical square patches is fabricated on 20 mil Roger/Duroid substrate with a relative permittivity of $\varepsilon_r = 2.22$. The square patch of 4.32 cm in dimension is excited along the vertical centerline 1.4 cm from the bottom radiating edge. For the reflector element, the notches of dimensions 0.1 cm x 0.2 cm are horizontally located at the mid-point along the two vertical edges. The spacing between the reflector and the fed patch is 0.3 cm. For the director elements, the notches are vertically located at the center of the horizontal edges, and have dimensions of 0.1 cm x 0.4 cm for the first director and 0.1 cm x 0.7 cm for the second director. The spacing between the fed patch and the first director is 0.155 cm, and between the first and the second director is 0.3 cm. The array is designed for a linearly polarized 45° beam at a frequency of around 2.3 GHz.

Results and Discussion: To determine the optimum design parameters, the array was first simulated with Ansoft Ensemble EM Simulation software. To begin, a fed patch with a single director was analyzed with the notches first located at the center of the horizontal edge and then at the center of the vertical edge. Results indicated that the notch position has strong impact on the beam direction. A significant forward beam scan to the right was resulted with the notches centered along the horizontal edge, while only a slight backward beam scan was observed with the notches located at the center of the vertical edge. For a fed patch with a reflector element, similar results were obtained except that the forward beam direction is now to the left. To optimize the beam directivity in a specified direction, proper element spacing and notch dimensions must be used. Since presently there is no established rule to determine these values, a systematic design approach was used starting out by first optimizing the element spacing for each parasitic element, and then the notch dimensions based on the criteria of best directivity in a specified beam direction. Fig. 2 shows the calculated co-polarization and cross-polarization patterns for the H-plane of the proposed Yagi array configuration depicted in Fig. 1. The calculated array gain was over 7 dB for elevation angles between 30° and 50° with a peak gain of 7.7 dB at around 40° at the designed frequency of 2.3 GHz. The calculated cross-polarization level is below 30 dB. The measured E- and H-plane patterns for the same array are shown in Figures 3 and 4 respectively. As expected, the E-plane pattern has a typical broadside beam similar to that of a single patch, and the H-plane pattern shows a 45° beam scan. The measured and the simulated results show good agreements.

Conclusion: In this letter, we present some general design procedures and results of a planar microstrip Yagi array for mobile satellite communications applications. Instead of using variable sized parasitic elements as reflector and directors to obtain beam scan, notched parasitic elements were used to produce the required proper phase delays. The array achieved a 45° beam scan with a gain of over 7 dB.

Reference

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2. Yagi H., 'Beam transmission of ultra short waves,' Proc. IRE, 928, (16) pp. 715-741.
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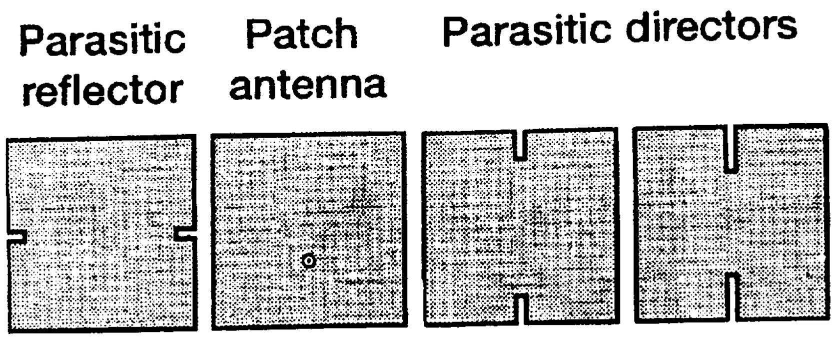

Fig.1 Schematic of a planar Yagi array with slotted parasitic elements (dimension=4.32 cm)

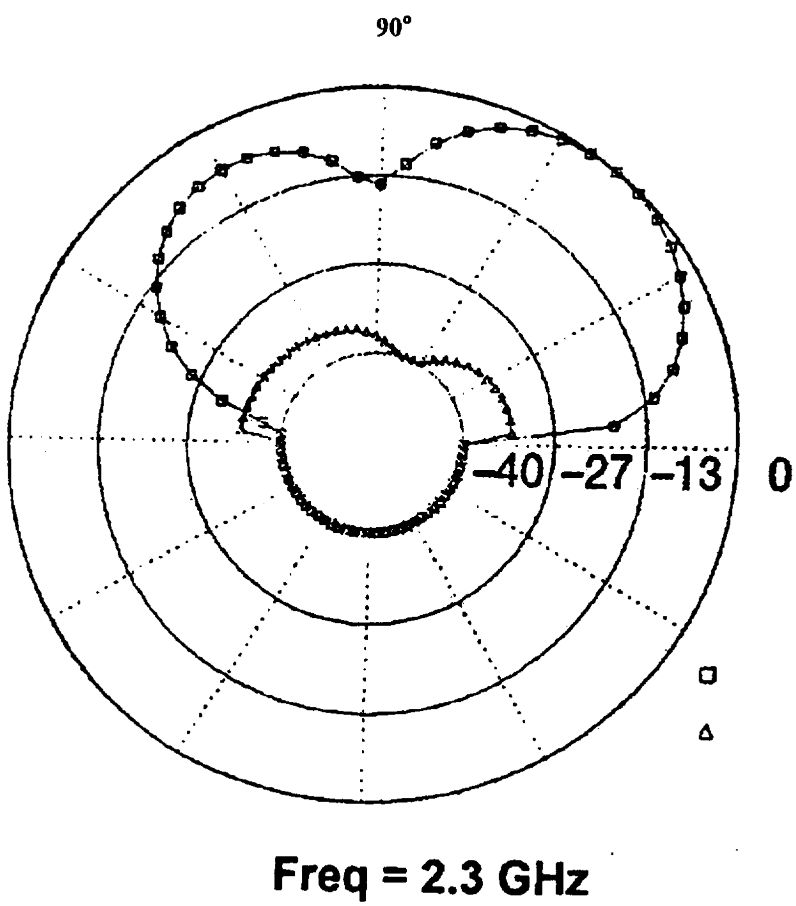

Fig. 2 Calculated co-polarization (□) and cross-polarization (△) patterns for the H-plane

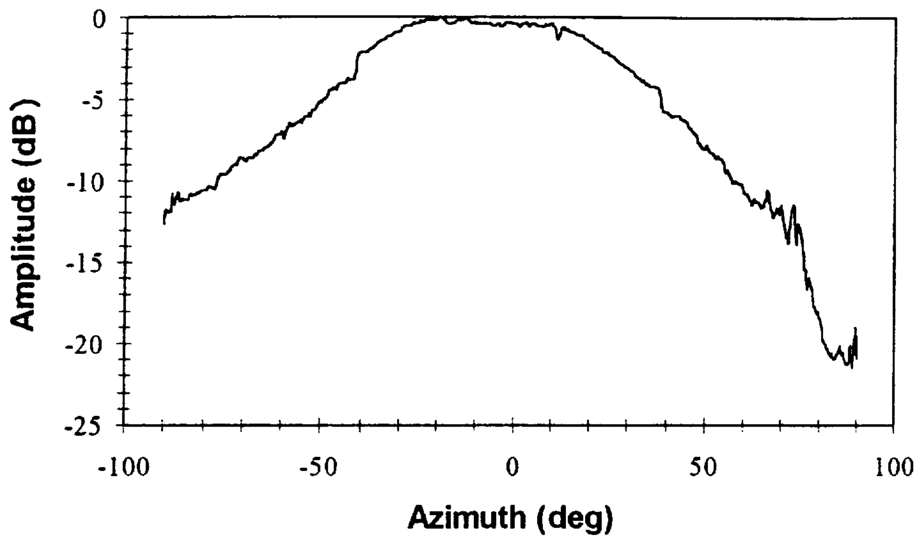

Fig.3 Measured E-plane radiation pattern

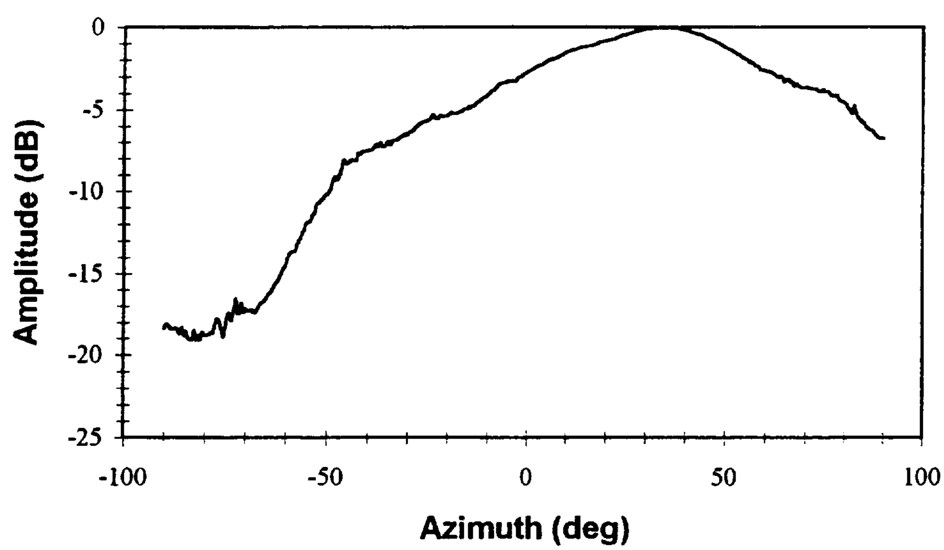

Fig. 4 Measured H-plane radiation pattern