A NOVEL DUAL-POLARIZED KU-BAND ANTENNA SUBARRAY

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ABSTRACT

The paper presents a novel design of a Ku-band (10,95...14,5 GHz) planar multilayered microstrip antenna using aperture-coupled stacked patch radiating elements with dual polarization capability. Frequency bandwidth of up to 26% (VSWR<2:1) and level of cross-polarization better than -30 dB have been achieved in both E- and H-planes of radiation pattern for the two orthogonal linear polarizations. Numerical results obtained by FDTD computer simulations are compared with experimentally determined characteristics of a manufactured antenna.

INTRODUCTION

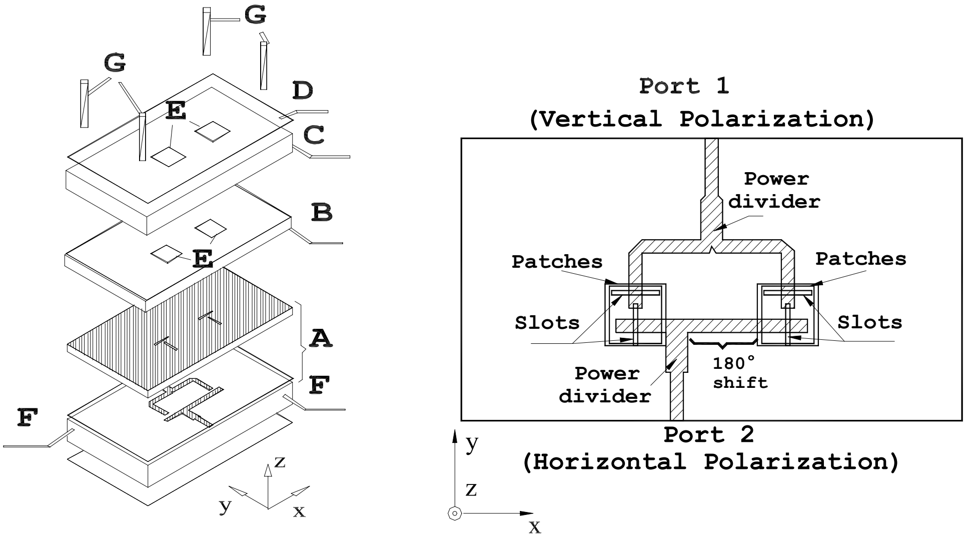
Future mobile satellite telecommunication systems are expected to require wide-band planar phased antenna arrays with dual polarization capability. The challenging trend is to increase the potential data rate of communication links due to both fully using a broadband frequency range and polarization diversity. Many efforts have been dedicated by researchers to the creation of broadband low profile antenna arrays during the last two decades. However, at present it is considered to be very difficult to realize both requirements of wide frequency band and dual linear polarization capability with a bandwidth of above 10% and a level of cross-polarization below -30 dB in planar arrays.

In order to meet the strict requirements of wideband dual linear polarization with low level of cross-polar radiation a combination of the stacked patch technique [1] with a symmetrical positioning of the coupled slots and antiphase microstrip feeding of slots from opposite sides is proposed.

DESIGN OF ANTENNA SUBARRAY

The basic design of the proposed novel multilayered dual-polarized antenna is explained according to Fig. 1. The integrated antenna system consists of two stacked aperture-coupled radiating elements and a microstrip feeding network, combining this radiators in terms of a two-element antenna subarray. The spacing between elements was chosen to be equal of 0,8 of wavelength at the center of the frequency range (12,7 GHz). The stacked antenna structure is manufactured by using four low-loss dielectric layers with different thicknesses and dielectric constants. Each layer was separately manufactured, parameters of them are given in Table. 1.

From the bottom side of layer **A** the microstrip circuitry is built up. Top side of **A** is a ground plane, where two pairs of symmetrically positioned orthogonal slots were etched for the excitation of orthogonal modes in the patch resonators (Pos. **E** in Fig. 1) located above (lower patch radiators are manufactured on the top surface of **Layer B** and upper patch resonators are manufactured on the bottom surface of layer D). A strict symmetry of slots significantly decreases electromagnetic interference effects between them [2] achieving the cross-polar radiation level down to about -32 dB. Two 50 Ohm-input microstrip ports (**Port 1** and **Port 2** in Fig. 1) are used to feed vertical and horizontal polarization channels, respectively. Microstrip power dividers of reactive type (T-splitters) have been used for the splitting of power between each of two antenna elements for both polarization networks. The input signals applied to the vertically polarized port enters in-phase after the power divider to the correspondingly oriented slots of the antenna elements. On the other hand, the input signal, applied to the horizontally polarized port and then divided by the reactive power dividers feeds the patch elements from the opposite sides, thus an additional 180 degree phase shift is needed to accomplish elements to radiate in phase. The latter was realized by different lengths of transmission line sections leaving the power divider as can be seen from Fig. 1. This enables the additional decrease of cross-polarization by approximately 6dB. It should be noted that such a kind of anti-phase feeding is frequency dependent and, generally, leads to unwanted frequency sweeping effect, like in series fed antenna arrays. However, in our case this effect appears to be not strong and finally achieved far-zone radiation patterns seems to be acceptable in the foresight of broadside direction of the main lobe for all frequencies within 26% of the operating band.



a) b)

Fig. 1. Geometry of proposed dual-liearly polarized multilayer microstrip antenna.
a) Perspective view. b) Top schematic view.

Table 1. Parameters of Layers

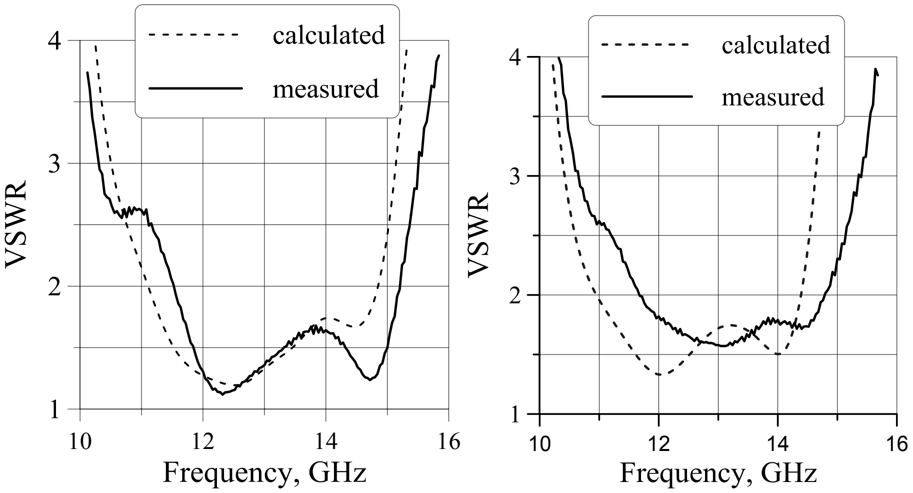
Layer	Substrate	Thickness	ε_r	Loss tangent
A	Duroid 5880	0,508 mm	2,2	0,0009
B	Duroid 5880	0,765 mm	2,2	0,0009
C	Rohacell 51 IG	2,5 mm	1,07	0.001
D	Duroid 5880	0,25 mm	2,2	0,0009

The composite sandwich structure assembly is situated quarter of a wavelength above the metallic screen at bottom side to suppress backward radiation. This distance is provided by special plastic holders that additionally contain rectangular plastic frames for making the whole assembly mechanically strong. When manufacture microstrip sandwich structures different dielectric layers have to be in precise alignment in horizontal plane for achieving satisfying electrical performance (shift between substrates should not exceed 0,002 of a wavelength). Furthermore one has to avoid potential air gaps between dielectric layers. This was achieved by several plastic screws (schematically shown Pos. **G in** Fig. 1) running through precisely drilled halls in all dielectric layers and keeping substrates together.

PREDICTED AND MEASURED CHARACTERISTICS

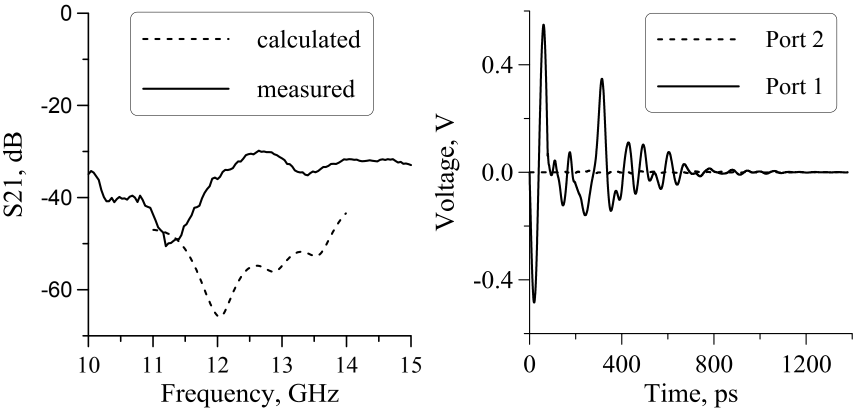
For the numerical analysis of the multilayered microstrip planar structure we choose the FDTD method, originally proposed in [3]. This method was also used for the multi-parameter numerical optimization of the antenna structure geometry and its feeding network. Theoretical and experimental (measured using a network analyzer HP8722C) results of VSWR for horizontal and vertical polarization channels in the frequency range 10,5…15,5 GHz are represented in Fig. 2. A strongly pronounced double resonance behavior of the stacked patch structure can be observed in both theoretical and experimental curves, which are found to be in good agreement for both polarizations within the full Ku-band (10,95…14,5 GHz). Fig 3a shows calculated and measured characteristics of isolation between two ports. The theoretical curve here proves the possibility to achieve an isolation between two port better than -40 dB within the full frequency range. This seems to be possible due to symmetrical positioning of coupled slots and antiphase feeding. Time domain simulated characteristics of input voltage for the case of **Port 1** excitation are presented in Fig. 3b. Here one can see vanishing value of voltage in **Port 2**. Certainly the characteristic of isolation are extremely sensitive to potential errors in manufacturing of the dielectric layers, to parasitic horizontal misalignment of the stacked assembly as well as to the real construction, framing and holding the tested sandwich structure.

In Fig. 4, 5 measured and simulated far-zone radiation patterns for both polarization channels at the center frequency (12,7 GHz) are presented, proving good dual linearly polarized performance with level of cross-polar radiation better than -30dB. Radiation patterns for other frequencies are similar and will be presented together with the future developments during the poster presentation.



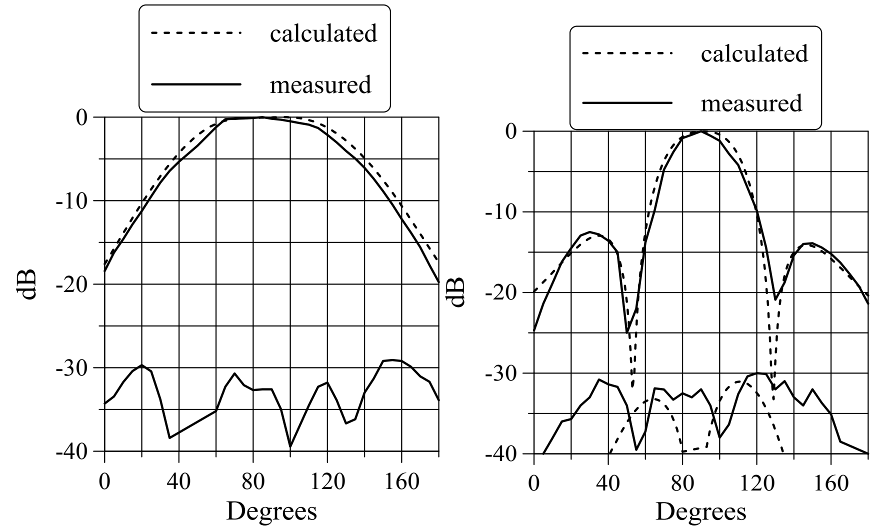
a) **b)**

Fig. 2. Calculated and measured VSW for a) horizontal polarizationl; b) vertical polarization.



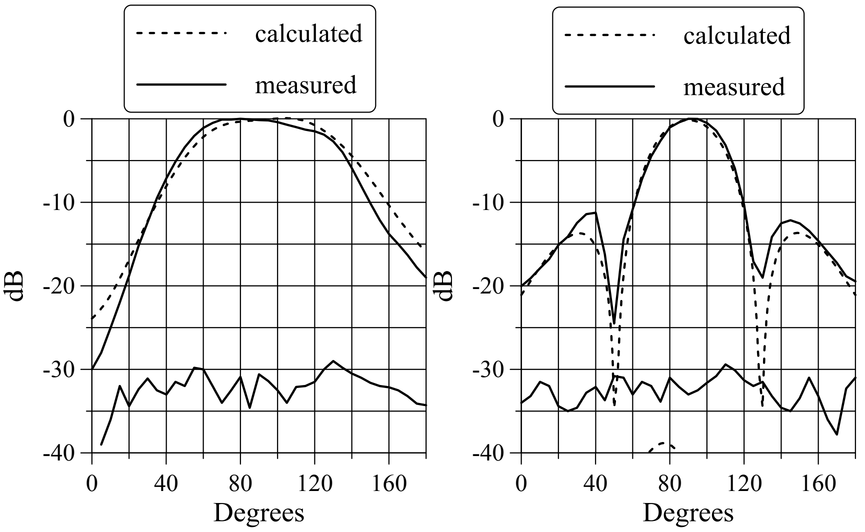
a) **b)**

Fig. 3. Characteristics of two-port isolation a) frequency domain. b) calculated in time domain.



a) b)

Fig. 4. Calculated and measured antenna radiation patterns (co- and cross-polarization) for the horizontal polarization channel at 12,7 GHz: a) YZ-plane; b) XZ-plane.



a) b)

Fig. 5. Calculated and measured antenna radiation patterns (co- and cross-polarization) for the vertical polarization channel at 12,7 GHz: a) YZ-plane; b) XZ-plane.

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