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Wideband linear array antenna in C-band for beam-pointing for SAR applications

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The design and development of a wideband dual polarized linear array antenna of 3 elements in C-band is presented. The centre frequency is 5.3 GHz. The single radiating element used in the array configuration is of stacked strip slot foam inverted patch (SSFIP). The antenna has been developed for beam-pointing of 10° and side-lobe level better than –15 dB by properly choosing the complex excitation co-efficients. The array antenna offers bandwidth of 22% for a VSWR of 2:1. The measured *S*-parameters and radiation patterns are presented.

1 Introduction

Antenna system plays a very important role in determining the overall system performance of air-borne and space-borne synthetic aperture radar system. Bandwidth and frequency allocation are the most significant parameters for satisfactory functions of Synthetic Aperture Radar (SAR)[1] system. The basic driving force for frequency and polarization selection is the application targeted for. The C- and L-band dual linear polarized SAR system are preferred for civilian applications like agriculture, soil moisture, forestry, flood mapping and ocean related studies. Thus, the antenna for SAR system must meet wide bandwidth characteristics, dual polarization, high polarization purity, reduced side-lobe level and back radiation. The antenna must also meet the characteristics of electromagnetic compatibility with associated electronic devices. Considering these requirements of SAR antenna, the choice of antenna system becomes very selective. Microstrip patch antennas are best suited for SAR applications because of the requirement of light weight, conformability and low cost[2]. But for wide bandwidth applications, conventional microstrip patch antennas cannot be used because of its narrow bandwidth characteristics and low efficiency.

In the present paper, a single patch antenna designed earlier[3] is used as a radiating element in the array antenna. This radiating element provides a bandwidth of the order of 26% around the centre frequency of 5.3 GHz for VSWR of 2:1. Pattern synthesis by a Woodward technique[4] was used to find the complex excitation co-efficient to achieve proper side-lobe and beam pointing. The measured *S*-parameters as well as the radiation pattern are presented.

2 Simulation and design

The design goals of the linear antenna was to achieve beam pointing by 10°, 3-dB main beamwidth 35°±2.5°, cross-polarization suppression better than –23 dB, side-lobe level better than –15 dB and gain 11 dBi. With these design goals in mind, the first step carried out was to determine the number of elements and the amplitude and phase distribution of the individual elements. The number of elements and the spacing between the radiating elements determine the 3-dB beamwidth as well as the gain of the array antenna. The amplitude distribution of the excitation of the radiating elements decides the side-lobe level of the radiation pattern which, in turn, affects the gain of the antenna. The phase distribution is required for beam shaping. In the present case, the requirement is beam pointing by 10°. The spacing between the radiating elements is a very critical parameter which must be chosen very carefully. The spacing between two consecutive elements should be less than λ, the wavelengths so as to avoid grating lobe[2]. On the other hand, the element spacing should not be very small which may result in higher mutual coupling between the radiating elements, thus deteriorating the radiation pattern performance. The accommodation of feed lines for both polarizations also becomes very difficult for very small spacing between the radiating elements. In order to get the desired radiation pattern, a number of iterations were performed with the pattern synthesis software[4] for different number of radiating elements and different sets of amplitude and phase distributions. The amplitude and phase for the desired radiation pattern is shown in Table 1.

The optimum element spacing is 0.5 λ, λ being the wavelength corresponding to the centre frequency of 5.3 GHz. It has been seen from Table 1 that the number of elements is 3 and with this element spacing and amplitude and phase distribution, the array antenna yields a radiation pattern with 3-dB beam width 37°±3° and gain 11 dBi with side-lobe level better than –18 dB.

The antenna element is composed of two square-stacked patches double-fed by two orthogonal and stacked microstrip lines through two crossed slots made in the ground plane and located underneath the centre of the patches[3]. Ansoft ensemble based on method of moment (MOM) technique was used to optimize and match the antenna to 50 Ω line which is the properly chosen impedance with respect to the array's network.

The ULTRALAM® 2000 with a dielectric constant of 2.45 was used as the material for the substrate of both the patches. The two substrates supporting the radiating patches are separated by a 'Rohacell foam' (ϵ_r = 1.07) of height 4.8 mm (Fig. 1). The two feed-networks below the ground plane which contains the crossed slots have been structured according to corporate feed distribution. The Ro4003® with a permittivity of 3.38 has been chosen as the substrate material for the two feed lines. The feed-networks are separated by a very thin substrate to enhance the port decoupling. A ground plane has been placed at the rear side of the antenna to shield electromagnetically the associated electronic devices from spurious back radiation. The dimensions of the crossed slots have been chosen so that its resonant frequency is far beyond the operating bandwidth of the antenna, thus minimizing the back radiation. The two orthogonal polarizations including microstrip lines are made in two different layers. This feeding technique is preferable as it improves the decoupling between the ports. The corporate feed networks for both the polarizations were optimized using LINMIC as well as ensemble software.

Table 1—Amplitude and phase of the radiating elements

Element No.	Relative amplitude	Relative phase
1	0.5	–45
2	1.0	0
3	0.5	45

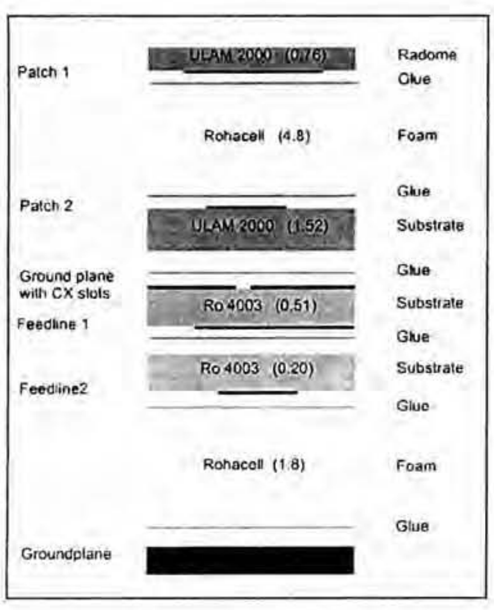

Fig. 1—Stacked patch antenna with different layered substrates and thickness used as radiating element (The number in the parentheses represents the thickness in mm)

3 Experimental results and discussion

In order to characterize the linear array antenna for input impedance and mutual coupling as a function of frequency, the return loss and coupling co-efficient were measured at both feeding ports. The bandwidth was around 22% at both the ports over the frequency range and coupling co-efficient varied between –24 and –30 dB. The measured *S*-parameters are shown in Fig. 2.

The measured array radiation patterns at both the ports for horizontal and vertical polarizations are shown in Figs 3 and 4 in elevation plane, respectively, at the centre frequency 5.3 GHz. The pattern at the azimuth plane is that of single patch antenna. Measurements were carried out for both the co- and cross-polarization. The radiation patterns exhibit at both the ports a first side-lobe level between –15 and –18 dB for both the planes. The cross-polar performance over the band was found within –23 and –25 dB. The beamwidth at elevation plane is 35° at the centre frequency. The measured gain is 10 dB. As

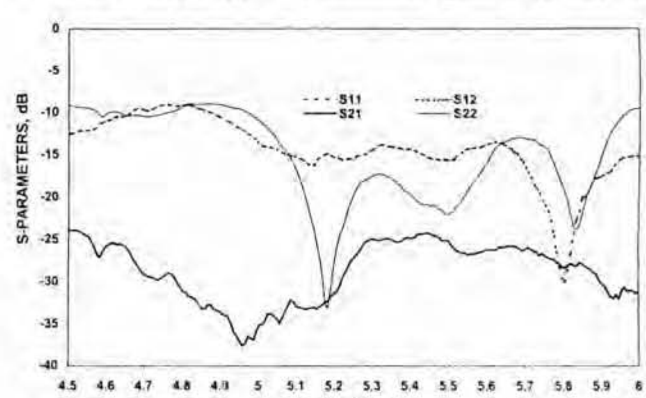

Fig. 2—Measured *S*-parameters (The data for curves S_{12} and S_{21} are almost identical and very difficult to demark the two.)

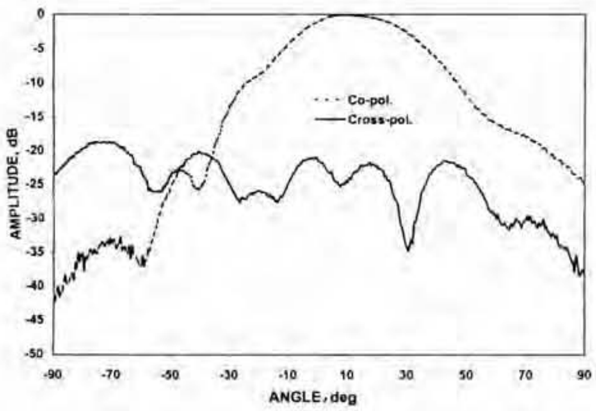

Fig. 3—Measured radiation pattern in elevation plane at port for horizontal polarization at 5.3 GHz

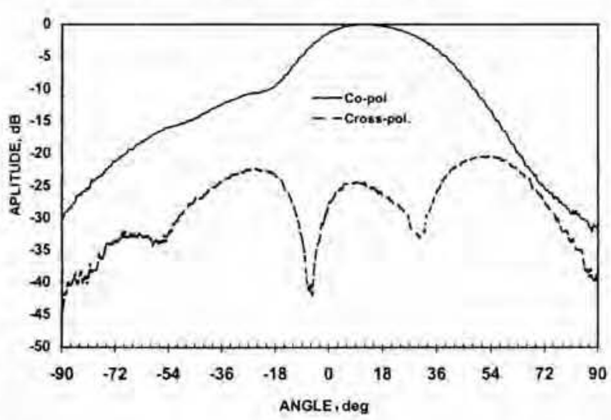

Fig. 4—Measured radiation pattern in azimuth plane at port for vertical polarization at 5.3 GHz

compared to the performance of the single radiating element which exhibits 26% bandwidth, the array bandwidth is reduced to 22%. This is attributed to the mutual coupling between the antenna elements and asymmetric phase distribution of the individual elements of the array and mutual coupling between the segments of the feed lines. All these factors also contribute to an increase in the cross-polarization level. This antenna exhibits broadband nature over the conventional patch antenna array where a bandwidth of 10% is achievable using the simple stacked strip slot foam inverted patch (SSFIP). The simulated and experimental data vary maximum by 4 - 5%.

4 Conclusions

Broad-band performance of the 3-element linear array antenna has been achieved using stacked SSFIP antenna with stacked feed lines for dual polarization. The measured results show desired bandwidth performance as well as very low back radiation of the order of –30 dB, thus ensuring better gain. The isolation between the ports is better than –23 dB and cross-polarization suppression is better than –23 dB.

Acknowledgement

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