Novel Broadband Slot Antenna with Low Cross-Polarization

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A new broadband slot antenna with low cross-polarization is presented. It is realized by introducing metal stubs in the aperture of a conventional bow-tie slot antenna. A spectral domain moment method analysis shows that the cross-polarization can be reduced by about 15 dB. The SWR remains below 1.6 in the bandwidth $f_{\text{upper}}/f_{\text{lower}} = 2.8$. Experimental data are in good agreement with theoretical predictions.

INTRODUCTION

Simple design and broadband impedance characteristics are prominent features of bow-tie antennas [1]-[3]. Aperture-type structures could, for instance, be interesting for MMIC and OEIC applications [4]. However, the cross-polarization increases with flare-angle and frequency. In addition, the bandwidth is still not wide enough for some applications. To enhance the bandwidth thin parasitic resonators have been introduced in the design of patch antennas [5]-[7]. In this paper, a similar technique is used to improve the performance characteristics of a bow-tie slot antenna fed by a coplanar waveguide (CPW).

DESIGN CONSIDERATIONS

Fig. 1 is a sketch of the modified bow-tie slot antenna (MBSA): it is realized by inserting metal stubs in the aperture. Two groups of thin resonators are thus formed: the basic resonators consist of two symmetrical pairs of bow-tie wings; they determine the main resonances; the other one is a subsidiary dipole between the stubs. Its resonances can be tuned independently by adjusting its length. The CPW feed was chosen here as it leads to a very simple antenna, and thus allows easy experimental handling. However, in contrast to more sophisticated feed techniques, such as a microstrip or a stripline on the backside of the substrate, it will contribute to the radiation pattern of the antenna.

As will be shown later, this has a negative effect on the cross-polarization. Therefore, to fully assess the potential of this new design, the contribution of the feedline was not taken into account in the theoretical investigations of the radiation characteristics. A spectral domain approach using roof-top functions in the applied Galerkin procedure was chosen for the analysis. Fig. 2 illustrates the discretization at the tilted edges of the bow-tie.
NUMERICAL RESULTS AND EXPERIMENTS
This new antenna was compared both theoretically and experimentally with a conventional bow-tie design. The following substrates were used: $h_1=0.254\,\text{mm}$, $e_{r1}=2.2$, $h_2=6.0\,\text{mm}$, $e_{r2}=1.1$, and $m_1=m_2=m_0$. The length of the stubs was varied. It determines whether the antenna behaves more like a bow-tie (short stubs) or a dipole (long stubs). Thus, bandwidth can be traded for low cross-polarization. The dipole formed by the stubs has a comparatively narrow-band resonance. Extending the dipole beyond the bow-tie slot allows to tune the impedance match at the lower end of the band without sacrificing cross-polarization. The length $v$ (Fig. 2) should not be too long, however, in order not to affect the phase center of the antenna at higher frequencies. The short CPW stub beyond the slot helps, in the usual manner, to adjust the reactive part of the input impedance.

The simulated distribution of the electric field in the aperture is presented in Fig. 3, the peaks arising from the discretization. Figs. 4a and b show the calculated and measured input impedance of an optimized MBSA and a conventional bow-tie antenna, respectively. The superiority of the MBSA is also demonstrated by the SWR-plot in Fig. 5. In a band $f_{\text{upper}}/f_{\text{lower}} = 2.8$ the SWR remains below 1.6. The gain of this MBSA peaks at 7.5 dB around 12.5 GHz. The improvement of cross-polarization reaches about 15 dB at this frequency (Fig. 6). The theoretical and experimental radiation patterns at 10.0 GHz are documented in Fig. 7 for both the MBSA and the conventional bow-tie slot antenna. The influence of the feedline can be seen here from the comparison between theoretical and measured cross-polarization.

CONCLUSION
A novel bow-tie slot antenna with metal inserts is presented. The design allows to combine the advantages of bow-tie antennas and dipoles, i.e. large impedance bandwidth and low cross-polarization. Theoretical performance assessments are well confirmed by experimental studies of a simple CPW fed prototype antenna. Further investigations, in particular on structures with more stubs and a design with a stripline feed, are currently under way.
Fig. 3 Electric field distribution on the modified bow-tie slot antenna

Fig. 4 Comparison of the measured (- - - - -) and simulated (- - -) input impedance, f=4 GHz - 24 GHz, Δ f=1.0 GHz. (a) modified bow-tie slot antenna: a=22.8mm, b=9.3mm, w=1.2mm, s=0.3mm, g=0.3mm, l=0.435mm, υ=2.7mm, v=3.6mm, d=4.8mm, t=0.3mm (b) conventional bow-tie slot antenna: a=22.8mm, b=9.3mm, w=1.2mm, s=0.3mm, g=0.3mm, l=0.435mm

Fig. 5 Comparison of measured SWR of the optimized MBSA (---) and a conventional bow-tie slot antenna (- - - - -): s=0.4mm, d=5.7mm (The others same as in Fig. 4)

Fig. 6 Comparison of calculated cross-polarization level of the optimized MBSA (---) and a conventional bow-tie slot antenna (- - -): d=5.7mm (The others same as in Fig. 4)

Fig. 7 H-plane radiation characteristics of (a) modified and (b) conventional bow-tie slot antenna at 10.00 GHz: calculated co-polarization, ---: calculated cross-polarization, -----: measured co-polarization, --------: measured cross-polarization
REFERENCES