A Novel Yagi-Uda Dipole Array Fed by A Microstrip-To-CPS Transition

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Abstract
We report the design and experiment of a novel Yagi-Uda dipole array fed by a MS-to-CPS transition. The Yagi-Uda array having one director on the same plane of the dielectric substrate as the driver element shows higher gain (9.1dB) than microstrip patch antennas and a much wider bandwidth (10.3%). The measured front-to-back ratio is about 15dB. This novel design should become an important alternative to tapered-slot type antennas for millimeter wave imaging array application.

I. Introduction
Millimeter-wave imaging array systems have become increasingly important in a number of scientific, military and commercial applications such as plasma diagnostics, contraband detection and automobile radars. A millimeter-wave imaging arrays consist of a large number of antennas integrated with detectors. Various kinds of antennas have been utilized in the array system so far.

Dipole antenna fed by coplanar strips (CPS) has problems with the surface wave excitation and needs special care in high frequency designs [1]. Twin-slot and twin-dipole configuration can be used to reduce the surface wave and improve the radiation pattern of the dipole antenna array [2]. Yagi-Uda elements combined with a substrate lens succeed to direct more power to the broadside direction [3]. The endfire tapered-slot antennas has also been used because of its high directivity and wide bandwidth. However the size of the tapered antennas is in general quite large so that it makes further integration such as monolithic fabrication of detectors and antennas difficult.

A novel configuration of printed Yagi-Uda dipole array is presented in this paper, as show in Fig.1. This antenna has endfire radiation patterns as compared to the broadside Yagi-Uda antenna of [3]. The Yagi-Uda array with a director and driver placed on the same plane of the high dielectric substrate directs the surface wave of the dipole antenna to the endfire direction. In addition, the groundplane of the microstrip line on the feeding port of CPS helps to reduce the surface wave travelling to the backside. This unique design results in an antenna with relatively high directivity, high gain and wide bandwidth. The antenna is more compact than a Vivaldi or tapered slot antenna and is fed by a standard microstrip line, which makes it easy for the monolithic integration of the antenna and detectors.

In this work, FDTD simulation and optimization is performed to design an X-band prototype of the newly proposed antenna. A wideband microstrip-to-CPS transition [4] is combined with the Yagi-Uda dipole antenna to obtain the balanced input signal for the CPS. The measurement shows higher gain (9.1dB), wider bandwidth (10.3%) in comparison with a normal microstrip patch antenna.

II. Antenna Design
Referring to the design curves obtained for the free space Yagi-Uda antenna [5], we can obtain
reasonably good initial dimension for the length of the director element. To find the optimal length of the director and the separation between the driver and the director, however, we need to use full-wave analysis. In this work FDTD simulation is used to calculate the return loss (S11), input impedance and the radiation patterns. The optimal design of the antenna is shown in Fig.1. The dimension of the antennas as follows: width=44mil, length of the driver=360mil, length of the director=216mil, separation between two element=82mil, gap of the CPS=10mil. The FDTD simulation of the input impedance roughly predicts the possible bandwidth of the antenna as shown in Fig.2. The normalized input impedance is close to 1 at 10GHz, indicating that a good impedance matching can be obtained around the frequency.

III. Measurement Results

Fig.3 shows the photograph of the fabricated X-band prototype. The dielectric substrate is duroid with ε_r=10.2 and 25mil thick. The input of the microstrip line is bent by 90 degrees in order to facilitate front-to-back ratio measurement. The measured S11 of the circuit is shown in Fig.4, and the bandwidth of S11 (<-10dB) is 10.3 percent. This bandwidth is much wider than that of normal patch antenna on a similar substrate.

The radiation patterns are measured at three different frequencies that are the center, the lower end and the upper end frequency of –10dB bandwidth of the measured return loss, and are shown in Fig.5(a)-(c). From this figure, the measured front-to-back ratio is as good as 15dB.
in three patterns, which is quite high for a two-element Yagi with only one director. The cross-polarization of the antenna is more than 15dB (13dB at the upper end frequency) below the co-polarization at the endfire direction. The gain of the antenna is measured to be 9.1dB at the center frequency that is also higher than a patch antenna can normally achieve.

IV. Conclusion

A new configuration of printed Yagi-Uda antenna is proposed and demonstrated successfully. The optimal dimensions of the antenna are obtained by FDTD simulation and very good performance of the antenna is obtained by the measurement. This new antenna is much smaller than a Vivaldi or tapered slot antenna, and its bandwidth is much wider than a normal patch antenna. It should find wide applications especially in millimeter wave imaging arrays.

Acknowledgement

This work is supported by ONR MURI under contract N00014-97-1-0508

References


Fig. 5(a) Measured radiation pattern of the Yagi-Uda dipole array at the center frequency (9.55GHz) of the –10dB bandwidth
Fig. 5(b) Measured radiation pattern of the Yagi-Uda dipole array at the lower end frequency (9.09GHz) of the –10dB bandwidth

Fig. 5(c) Measured radiation pattern of the Yagi-Uda dipole array at the upper end frequency (10.04GHz) of the –10dB bandwidth