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Circularly Polarized Stacked-Yagi Antenna with Logarithmic Spiral Elements for E-band Applications

Behnam Zarghooni and Ke Wu
POLY-GRAMES, École Polytechnique de Montréal, Montréal, Canada

Abstract

This paper presents a new stacked-Yagi antenna operating in the E-band that uses logarithmic spiral elements to achieve an ultra wideband response and circular polarization. An SIW structure is used to excite the spiral structure as the single element and a matching post is used as a balun. This element is then used in a vertical stacked-Yagi configuration in order to increase the antenna gain. According to the simulation results, the resulting stacked-Yagi antenna provides a peak gain of 11.5 dB and a CP bandwidth from 71 to 86 GHz.

1. Introduction

Currently there is a bandwidth of 10 GHz available in the E-band which can be used for multi Gbps applications. This spectrum includes two sections of 71-76 GHz and 81 to 86 GHz. One of the challenges that should be overcome for working in the millimeter waves is the high propagation loss for which high gain antennas are required. Stacked-Yagi is a small, low-cost and high-gain antenna that is proved to be very useful for high-gain MMW applications. This antenna is introduced in [1] for the first time and it consists of vertically stacked circular patches operating at the frequency of 30 GHz that provides a bandwidth of 6% and a gain of 10 dBi. However, the authors have used a very simple circular patch as the element that can limit the antenna features in certain ways. To achieve a better performance, we need to use more sophisticated elements. For example, in terms of the circular polarization, (which is considered as a feasible solution for future MMW MIMO communication systems) patch elements suffer from narrow axial ratio bandwidth. Spiral antenna is a good candidate in this regard because it is a well known structure that provides a wide AR bandwidth. However, spiral antennas have their own problems such as having complex feed that makes it hard to be used in an array. Recently, in [2] a novel CP antenna is presented based on an Archimedean spiral structure operating in the 57-64 GHz band.

In this paper, a new design for a wideband stacked-Yagi antenna with circular polarization is presented. This design uses logarithmic spiral elements to achieve an ultra wideband antenna. In the following sections, first the spiral element is designed for the E-band and then it is used in a stacked-Yagi structure to achieve the best performance.

2. Spiral Element

Spiral antennas are conventionally used in applications such as sensing, GPS and military where wideband and low-profile structures are needed [3]. Figure 1 shows the schematic view of a logarithmic spiral that is used to design the antenna element. The maximum dimension of the spiral is 1.8 mm.

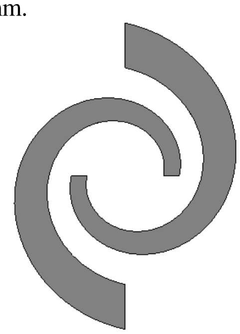

Figure 1. The proposed spiral element.

There are a few issues with this structure that should be overcome before using it as the single element. First of all, because of the input impedance of the spiral, a balun is required for the matching. The second issue is that several turns are needed to realize the circular polarization and it might be not feasible in MMW applications. The design presented in [2] proposes a change in the lengths of two arms of an Archimedean spiral that makes it possible for circular polarization. The schematic shown in Figure 2 is in fact a modified version of this design with a different type of spiral in the E-band.

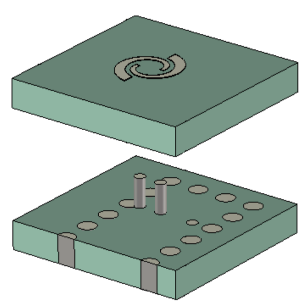

Figure 2. Schematic view of the single element antenna.

In this structure, Rogers RT/5880 with the thickness of 0.508 mm is used as the substrate and it is simulated in CST Microwave Studio and its reflection coefficient is plotted in Figure 3.

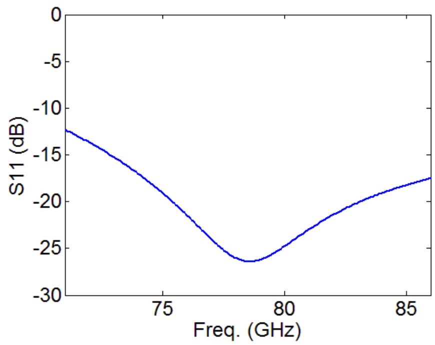

Figure 3. Simulated reflection coefficient of the logarithmic spiral element.

As shown in Figure 3, the logarithmic spiral antenna has a very wideband behavior and there is no problem to have matching over the frequency range of 71 to 86 GHz. The normalized radiation pattern of the antenna at 78 GHz is shown in Figure 4 and the simulated peak gain of around 7 dB.

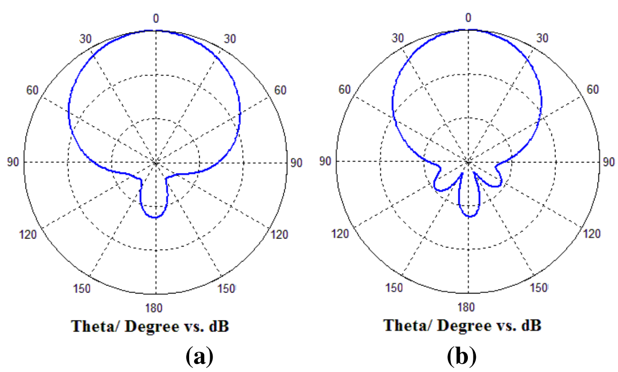

Figure 4. Normalized radiation pattern of the logarithmic spiral element in E-plane (a) and H-plane (b).

In the following section, we are going to use this single element in a vertically stacked-Yagi configuration to increase the antenna gain.

3. Spiral Stacked-Yagi Configuration

The design procedure of the stacked-Yagi is similar to the conventional Yagi antenna [4]. Here, we used a total number of four elements including the radiator. The schematic view of the proposed antenna is shown in Figure 5.

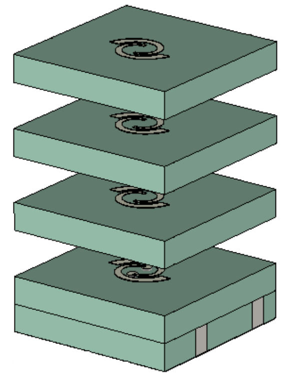

Figure 5. Stacked-Yagi configuration.

The spacing between the elements are around 0.15 wavelength and the size of parasitic elements are 0.78 of the radiator. All the elements are printed on the same Rogers RT/5880 substrate. The reflection coefficient and axial ratio of the antenna are plotted in Figure 6.

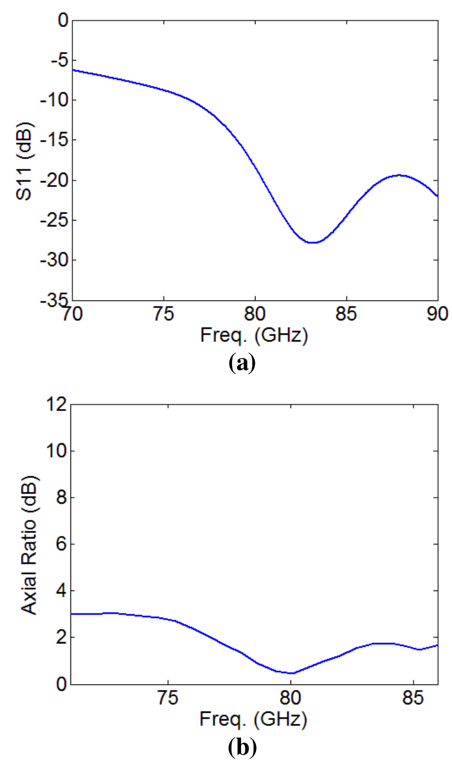

Figure 6. Reflection coefficient and radiation pattern of the stacked-Yagi antenna.

As plotted in Figure 6, the axial ratio is below 3 dB in almost all the frequency range. Normalized radiation pattern of the stacked-Yagi antenna is plotted in Figure 7. The peak gain is 11.5 dB at 78 GHz and the ground plane at the bottom of structure results in a unidirectional pattern.

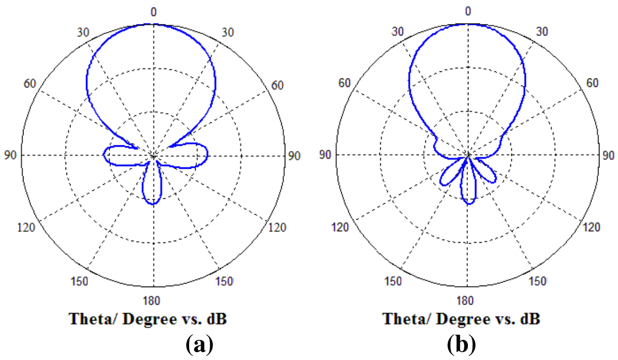

Figure 7. Normalized radiation pattern of the stacked-Yagi in E-plane (a) and H-plane (b).

Having a large bandwidth and an axial ratio below 3 dB over the operational frequency range and also a high gain, the logarithmic spiral stacked-Yagi antenna is a good candidate for future E-band applications over the frequency range of 71 to 86 GHz.

4. Conclusion

In this paper a new circularly polarized vertical stacked-Yagi antenna has been presented over the frequency range of 71-86 GHz. This antenna utilizes a logarithmic spiral structure for the radiating and parasitic elements. The spiral design leads to a wideband performance as well as the enhanced CP bandwidth. The antenna gain is also increased due to the stacked-Yagi configuration.

5. References

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