Practical Realization of a Microwave Bessel Beam Launcher

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Abstract

An experimental setup is realized to practically generate Bessel beams in the microwave regime. The setup, which consists of a series of circular loop antennas inserted coaxially inside a circular metallic waveguide, excites the waveguide's transverse-electric modes such that their superposition forms a Bessel beam at the open-end of the waveguide. The excitation currents are calculated from the needed excitation coefficients of each guided mode, which, in turn, are calculated from the modal decomposition of the beam. The efficiency of the setup is evaluated and the obtained experimental results are compared to the theoretical estimates.

1. Introduction

Bessel beams are non-diffractive solutions to Helmholtz equation and were first introduced in [1], where it was shown that their transverse localization is independent of their propagation distance. While the ideal Bessel beam extends indefinitely in the transverse plane, making it any attempt of practical realization impossible, it was shown that an approximate realization of the ideal beam is possible. The experimentally verified approximation to the Bessel beam exhibited the same qualities of the ideal beam over a finite distance [2].

Although generation of Bessel beams in the microwave range has been previously reported [3], such approach generated an approximation to the scalar wave equation solution, not the vector wave equation one. Here, we demonstrate experimentally the approach to vector Bessel beams generation in the microwave regime as what has been theoretically proposed in [4]. The proposed approach offers a lot of flexibility in manipulating the beam properties (intensity, spot-size, and modulation) as the generated beam is controlled directly by the excitation currents.

In the theoretical approach, the vector transverse-electric (TE) Bessel beam solution is derived from the scalar one. Next, the beam is expanded in terms of the circular waveguide's propagating TE modes using the power orthogonality feature of the modes, and the modes excitation coefficients are determined. Finally, a linear system of equations is constructed to relate the modes of the expanded beam to the fields excited by the circular loop antennas. The solution of the linear system determines the excitation currents of the antennas.

2. Experimental Setup

The experimental system for generation of microwave range monochromatic CW Bessel beam is implemented at operational frequency of 10 GHz. This system consists of a continuous wave microwave source, Wilkinson 1x8 power divider, 8 individual power amplifiers/ attenuators and phase shifters and a beam launcher structure integrated with 8 loop antennas. A schematic diagram of the launcher is presented in Figure 1.

Beam Launcher is constructed as a 90cm section of a 27cm diameter cylindrical waveguide. Open (launch) end of the waveguide is fitted with a 9cm wide flange. Loop antennae of sequentially decreasing radii positioned in the pre-specified positions within the waveguide. Loop antennae diameters and positions are shown in the Table1. Positions are calculated from the aperture end of the waveguide.

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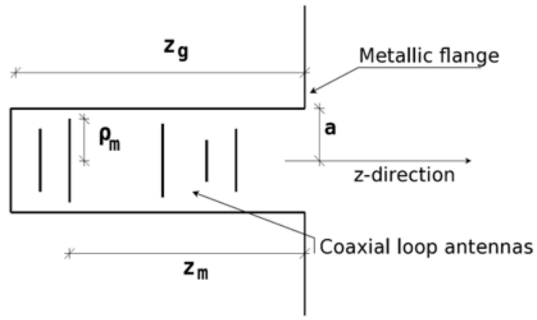

Figure 1 A schematic diagram of the Bessel beam launcher.

Loop Antenna	Diameter (cm)	Position from aperture (cm)
1	25.5	13.5
2	22.5	22.5
3	19.5	31.5
4	16.5	40.5
5	13.5	49.5
6	10.5	58.5
7	7.5	67.5
8	4.5	75.5

Table 1.Launcher system antennae sizes and positions within the waveguide.

Excitation power supplied to the loop antennas is at the CW frequency of operation and individually controlled by amplification/attenuation and phase shift. This application of excitation power is obtained by using a single microwave source and splitting the available power into 8 channels by means of a 1x8 Wilkinson power divider. The divider is implemented using thin film technology on fused silica substrate.

Each excitation signal is power adjusted to the required level using a voltage controlled amplifier (attenuator) with voltage controlled gain (attenuation) with a minimal step of 0.5dB and total dynamic range of approximately 20dB.

In addition each excitation signal is brought into the proper phase with a voltage controlled phase shifter. Phase shifters are implemented on the basis of branchline coupler with GaAs microwave hyperabrupt diodes as variable loads. Phase shift provided is of 180° range.

This experimental setup is expected to provide a Bessel Beam with 4 annular rings and with peak power located 12.75cm from the aperture. Transverse intensity of the generated beam is expected to be confined within a space equal to the diameter of the aperture. Presently this experimental setup is in progress and results are expected in a timely manner.

3. References

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