High Frequency and High Gain Two-Element Collinear Antenna Array

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***Abstract*— this paper presents a new collinear antenna array that can realize high omnidirectional gain at 30GHz band. The array are formed by two stacked biconical antenna elements fed parallel through a balun, and each element can produce an omnidirectional gain of around 9.5dBi. The measured -10-dB impedance bandwidth of the antenna is 26.2-30.2GHz. Within the bandwidth, the antenna achieves a high measured omnidirectional gain of around 12.5dBi corresponding to about 5° 3-dB beamwidth.**

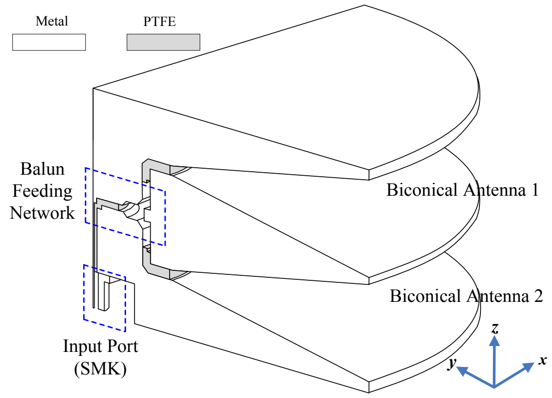
Keywords—collinear array, omnidirectional antenna, gain.

I. Introduction

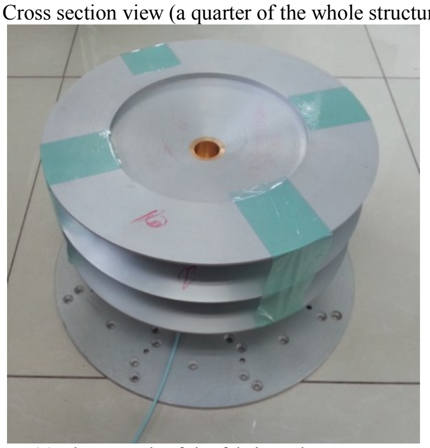
Omnidirectional antennas are widely used in radio broadcasting, cellular network, walkie-talkies, wireless local area network, etc. Dipole, monopole, biconical, discone, loop antennas are the most common forms of omnidirectional antennas. However, for most omnidirectional antennas, their gains are quite limited, which restricts their applications. For example, typical peak gains of biconical and discone antennas are from 1 to 7dBi. Actually, few single omnidirectional antennas, which can reach a gain of more than 10dBi, have been proposed [1].

Adopting antenna array is an effective way to improve gain. The simplest and most widely used omnidirectional antenna array is collinear array. It is realized by stacking several low-gain omnidirectional antenna elements collinearly along an axis, and each element are fed in either series or parallel. Franklin array, array with meander-line phase reversal and array with transposed coaxial sections are the most common series fed collinear arrays [2]. Planar versions of this kind of arrays have also been developed [3-5]. Series fed collinear arrays are simple in structure, but they suffer from narrow bandwidth and their beam directions vary with frequency [2]. Parallel fed collinear arrays have better bandwidth performance and stable beam direction. However, their complex feeding networks cause high transition loss that degrades the antenna efficiency [2, 6-8]. Due to the high loss at high frequency bands, former collinear arrays mainly operate at VHF and UHF bands and are not suitable to work at higher frequency. Actually, omnidirectional antenna or array with a gain of more than 10dBi operating above 20GHz hasn't been presented before.

This paper intends to develop a high frequency (30GHz) collinear antenna array to produce high omnidirectional gain.



(a) Cross section view (a quarter of the whole structure)



(a) Photograph of the fabricated prototype

Fig. 1. Geometry of the proposed collinear array.

By stacking two high gain biconical antennas that are fed differential through a balun, a parallel fed collinear array showing a high gain of around 12.5dBi is designed. Since the antenna is a solid of revolution, it also shows a good radiation pattern omnidirectivity.

II. Antenna Array Design, Simulation and Measurement

A. Antenna Array Design

The geometry of the collinear array is shown in Fig. 1. As can been seen, it is formed by four components, namely, two biconical antennas, a balun and a SMK connector as the input port of the array. Biconical antenna element and the balun are optimized separately in HFSS [9], and then assembled to build the array.

The geometry of the two antenna elements is shown is Fig. 2, and they are symmetric about the center plane between them. The height and the radius of each biconical antenna element are about 5.67 and 16.8 wavelengths of the operating frequency (30GHz). The overall height the proposed antenna is thus about 12 wavelengths. The input ports of the two elements are coaxial waveguides. From the vector E-filed distribution in the two elements, it can be found that the excitations of the two elements must be 180° in difference. Only in this way, the E-fields on the cylinder apertures of the two elements are the same in phase, which ensures a high gain omnidirectional radiation on the elevation plane. Therefore, two antenna elements should be fed by two subports of a differential port. This feeding scheme can be regraded as parallel feeding. It is the same to the collinear arrays using other parallel feeding methods. Due to this, the beam direction of proposed array does not vary with frequency.

Since the input port of the collinear array is coaxial, that of the balun should also be coaxial. The geometry of the balun designed to feed the two elements is shown in Fig. 3. All three single-ended ports of the balun are coaxial waveguide but with different sizes. The input port is a SMK connector that is 50ohm, and the geometry of the output ports matches the input ports of the two antenna elements. EM energy is fed from the input port of the balun and then excites parallel plate TEM wave propagating radially in the radial transmission line. When the TEM wave reaches the edge of the radial transmission line, it is divided into two parts. One part goes up while the other goes down to the two single-ended output ports, respectively. These two parts are naturally out-of-phase, as shown in Fig. 3. Several steps are included inside to improve the matching. As can be seen, the working principle of the balun is the same with that of E-plane T [10]. The balun shows very good performance, and the simulated phase and magnitude imbalances are less than 0.12° and 0.045dB from 24 to 32GHz, respectively.

The two antenna elements and the balun are used to build the collinear array. The antenna consists of seven independent parts. Three of these seven parts are metal, which are the main body of the antenna, and three are PTFE, which are used to support the main body. The SMK connector is a customized one with a long probe to excited parallel plate TEM wave. An aluminum disk is also used at the bottom of the prototype as the base to support the whole structure.

B. Antenna Array Simualtion and Measurement

The simulated E-filed distribution at 29GHz inside the array is shown in Fig. 4, from which, we could observe uniform and symmetric E-filed destruction inside the two elements. The simulated reflection coefficient of the proposed antenna is given in Fig. 5. The reflection coefficient is less than -20dB within the band from 25.9 to 29.8GHz. The simulated normalized co-polarization radiation patterns at 27, 28 and 29GHz are depicted in Fig. 6, from which we could observe a sharp beam with a 3-dB beamwidth of around 5° in the elevation plane. The simulated gain is given in Fig. 7. The simulated gain is around 12.5dBi within the bandwidth from 26.5 to 31.5GHz, but it drops nearly 2dB at 32GHz due to the mismatching.

A prototype is fabricated and then measured. Its reflection coefficient is measured by an Agilent vector network analyzer N5244A. As can be seen, the measured reflection coefficient is worse than the simulated one. From 26.2 to 30.2 GHz, the

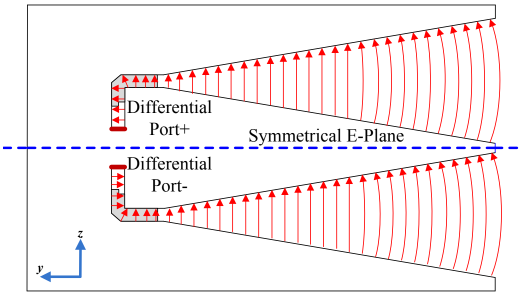


Fig. 2. The geometry of the two stacked antenna elements. Only half of the structure is shown.

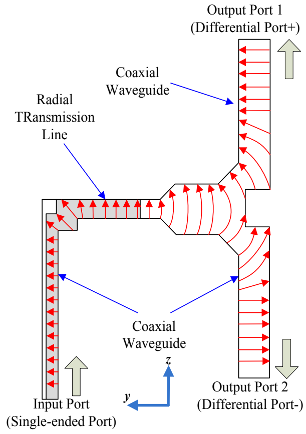


Fig. 3. Geometry of the coaxial balun. Only half of the structure is shown.

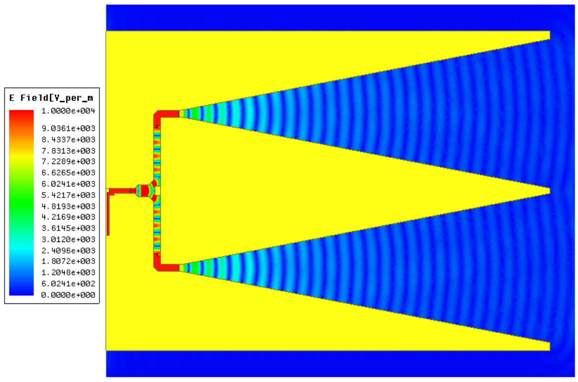


Fig. 4. Simulated E-filed distribution (magnitude) in the proposed collinear array at 29GHz. Only half of the structure is shown.

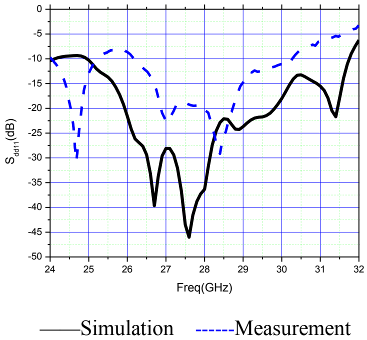


Fig. 5. Simulated and measured reflection coefficients of the proposed collinear array.

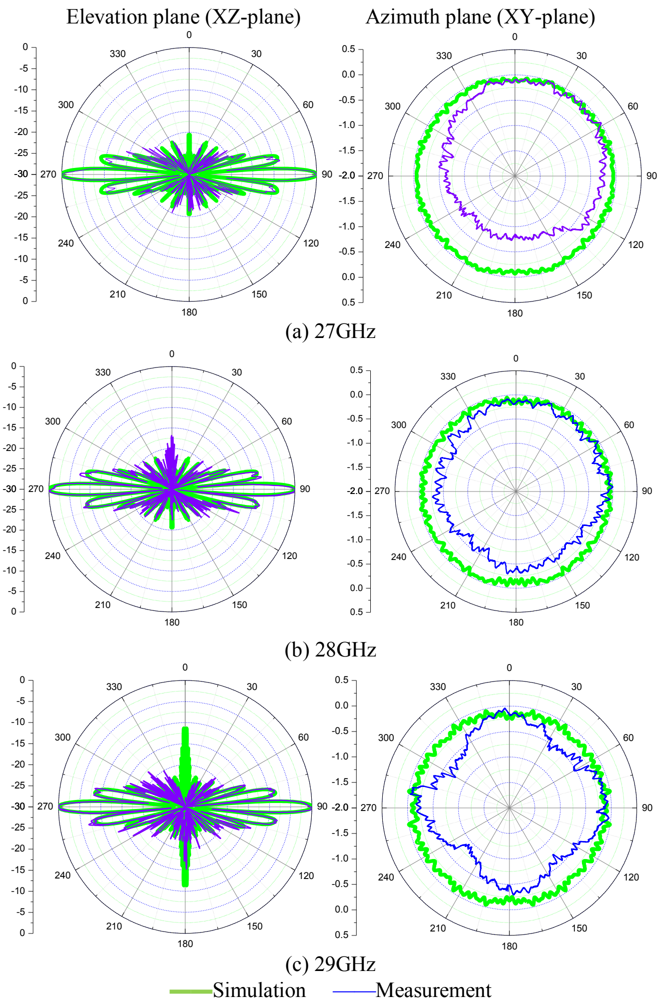


Fig. 6. Simulated and measured normalized co-polarization radiation pattern of the proposed collinear array.

measured reflection coefficient is lower than -10dB; and from 26.6 to 28.9GHz, it is lower than lower than -15dB. The shape of the measured reflection coefficient is similar to that of the simulated one, but shifts toward the upper right, as shown in Fig. 5. The degradation of the measured reflection coefficien is mainly due to the fabrication error of the SMK connector and input part of the balun. The radiation pattern and gain of the prototype is measured by a far-field measurement system.

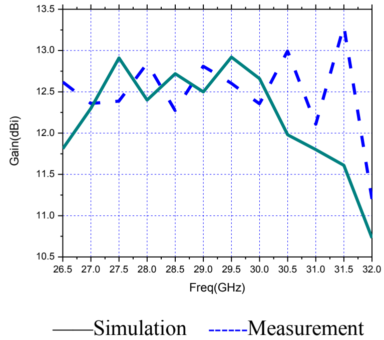


Fig. 7. Simulated and measured gain of the proposed collinear array.

Fig. 6 depicts the measured normalized co-polarization radiation patterns at 27, 28 and 29GHz, which match well with those from the simulated ones. The 3-dB beamwidth is around 5° at these frequencies. Since the measured cross-polarization level is lower than -20dB at these three frequencies, measured cross-polarization radiation pattern isn't given in the Fig. 6. Measured gain is better than 12.2dBi from 27 to about 30.2GHz, as given in Fig. 7, which generally agrees with the simulated gain.

III. Conclusion

A new parallel fed collinear array realizing high unidirectional gain at high frequency is presented. By stacking two high gain biconical antennas differentially fed through a coaxial balun, a high omnidirectional gain around 12.5dBi can be produced at 30GHz band. The performances of the proposed antenna can be further enhanced by using better fabrication process. Though the proposed antenna is designed to operate at 30GHz band, its structure can also be used to implement collinear array working at higher frequency. On the other hand, higher omnidirectional gain can also be realized by stacking more elements in a similar way.

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