Integration Design of High Efficiency Reflectarray and Transmitarray for Millimeter Wave Wireless Communications

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Abstract

In this paper, the research progress of reflectarray and transmitarray for millimeter wave (mmW) wireless communications has been briefly reviewed. The newly released Q-band spectrum (40.5-50.2GHz) by Chinese government is assigned to support wireless communication business for both long- and short-range scenarios. To meet the requirement of high gain antenna for long-range case, reflectarray and transmitarray have been developed and exemplified in Q band. A new type of integration design of folded reflectarray and transmitarray antennas have been proposed, and planar feeds are adopted instead of conventional bulky feeds, e.g. horn antenna or open waveguide. The used planar feed give the possibility for integrating the entire reflectarray/transmitarray with active/RF circuits directly, and no additional transition is needed between the antenna and RF circuit, which will highly improve the performance of the system.

***Key words*-reflectarray, transmitarray, millimeter wave, integration**

1. Introduction

The exploration of millimeter wave (mmW) frequency spectrum has been widely carried out in recent due to its obviously potential merits that are suitable for wideband, ultra high date rate wireless communications. In addition, the crowded frequency spectrum in microwave band pushes researchers and engineers shifting their attentions from low frequency to mmW band. Several mmW wireless communication standards/plans have been raised and related researches have been conducted for different applications. For instance, V-band (60GHz) and E-band (70-80GHz) standards hold the dominant position, especially in North America, Japan, and etc. Their counterpart in China is a newly released mmW standards, generally called Q-linkpan, and the ministry of industry and information technology of China has assigned the spectrum of Q band (40.5-50.2GHz) to this standard, as illustrated in Fig. 1 [1]. Q-linkpan includes both long-range and short-range wireless communication scenarios, aiming to provide link or back haul service in long distance, and indoor access and connection in short range for ultra throughput communication service, which are corresponding to ‘link’ and ‘pan’ (personal area network) contained in its name.

For the long-range case, high gain antenna is demanded, and the efficiency of the antenna is very critical since it determines the antenna size and the energy consuming of the system. High gain, high efficiency antenna design is a challenge for millimeter-wave (mmW) long range wireless communication [2]. As is well known, the conductor loss and radiation loss are increased evidently with the operating frequency goes up. Thus, the conventional antenna array, comprising of many low-gain elements, usually suffer from severe loss due to its essentially complicated feeding network [3]. The reflectarray and transmitarray [4-8], inspired by conventional parabolic reflector antenna and lens antenna, are more preferred as effective solutions for implementing high gain antennas in mmW bands due to they adopt air feed scheme and complicated feeding network is avoided.

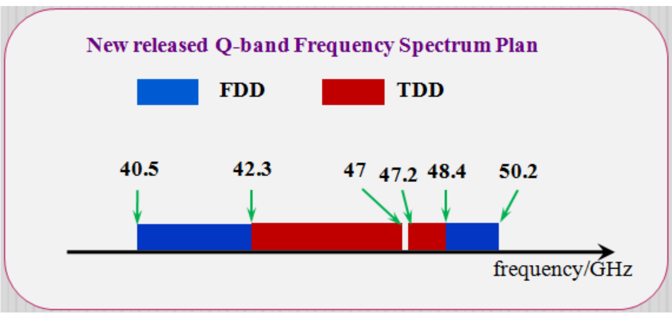


Fig. 1 Frequency Spectrum Assignment for Q-linkpan.

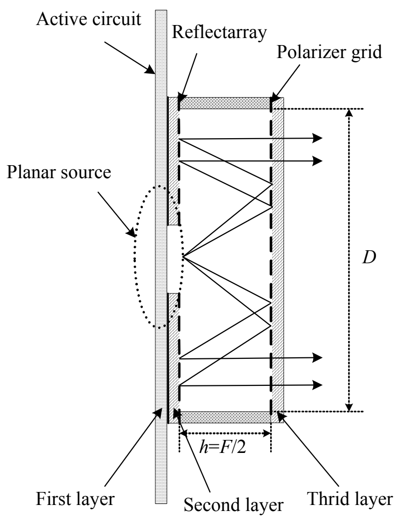


Fig. 2 Geometry of integrated folded reflectarray antenna.

In general, reflectarray is composed of a planar reflector and a primary source [4], i.e., horns or open waveguides. However, these used primary sources always have bulk sizes, and a transition between the antenna and planar circuits is necessary. Again, the transition will bring additional insertion loss to the entire system, and cause an integration issue or difficulty, especially in mmW band. These problems are also encountered in the design of transmitarray. To alleviate these problems, in this paper, an integrated approach of the reflectarray/transmitarray and a planar primary source is proposed, which ensures that the proposed reflectarray possesses the capability of directly integration with mmW planar circuits and a high gain as well high efficiency radiation can be achieved.

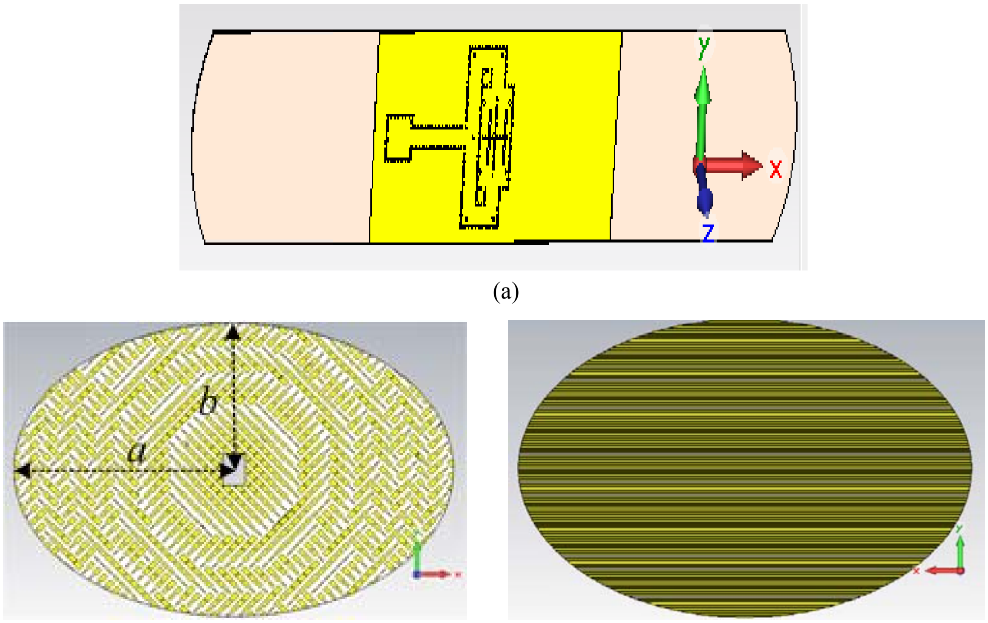
2. Integrated Folded Reflectarray Antenna

Generally, the folded reflectarray antenna (FRA) can achieve an evident size reduction than conventional reflectarrays [7], and the aperture blocking caused by the feed is also less. As is well known, it is quite difficult for FRA to realize circular polarization.

In this paper, we chose the FRA to implement our integration design. The scheme of the proposed integrated FRA is shown in Fig. 2. The antenna consists of a planar source, a reflectarray, and a polarizer grid that are arranged in sequence as the first, second, and third substrate layers shown in Fig. 1, respectively. The planar source can be any antenna or array with planar form, e.g., microtrip patch antenna (array), slot antenna (array), SIW antenna (array) and etc. Here, a SIW slot antenna array with four radiating slots, as shown in Fig. 3(a), is chosen due to it can provide a moderate gain of 11dBi, and more important thing is that SIW has very low insertion loss than conventional planar transmission lines, especially in mmW band. A common reflectarray composed of dipoles [7] is used here to provide focusing and twisting functions, as shown in Fig. 3(b). The top metal layer of the planar source is shorted to the ground plane of the reflectarray, or they can be fabricated by multi-layer PCB process. Furthermore, the shared ground plane of the planar feed and the reflectarray provide the possibility for directly integrating active or passive circuits on the back side of the antenna, such as filters, diplexers, and integrated transceivers etc. No extra transition is required, and the sensitivity of the RF-end can be potentially improved. The polarized grid (Fig. 3(c)) is supported by screws with a certain distance to the reflectarray. Thus, the entire antenna keeps the characteristics of conventional FRA, and simultaneously has certain advantages, such as small size, easy integration, low loss and etc. Thus, the proposed antenna is very promising for high density integrated mmW systems.

The operation principle of the planar source-fed FRA can be generally described as follows. The planar source illuminates the polarizer grid with a linearly polarized wave and then the wave is reflected back toward the reflectarray. Next the reflectarray focuses the beam and twists the polarization of the incident wave. Finally, the focused and twisted plane wave passes through the polarized grid and radiate outward.

As the planar source is used, the design method of the proposed integrated FRA has several special considerations. First, the phase center of the planar source should be well calculated, and the planar source should be accurately placed in order to keep its phase center right at the focus point of the reflectarray. Thus, the distance between the feed source and the polarized grid is differently determined from that of conventional FRA fed by horn antenna. If the phase center of the planar source is offset from the focus point, it will cause an error and decrease the efficiency. Second is that since the planar source is an array antenna comprised of 4 slots, as shown in Fig. 2, its radiation pattern is evidently asymmetrical due to the dipole-like radiation performance of the slot, which will increase the spillover loss. Therefore, the shapes of the reflectarray as well as the polarized grid have been modified from conventional circular one into an elliptical one, as shown in Fig. 3(b). The elliptical is determined from the beamwidthes of the E- and H-plane of the feed source. By taking these effects into account, the efficiency of the proposed integrated FRA can be sharply improved.



(a)

(b) (c)

Fig. 3 Structures of the proposed integrated FRA. (a) Planar SIW slot array antenna, (b) polarized grid, (c) reflectarray.

The integrated FRA has been exemplified at Q-band, aiming to achieve a high gain larger than 30dBi. The overall size of the antenna is 150×98×π/4mm2 and through the experiment, the efficiency of 49% is achieved at 44 GHz with the corresponding gain of 31.9dBi as indicated in Fig. 4. The beamwidthes of E- and H-plane of the proposed integrated FRA are 3.5° and 4.9° , respectively.

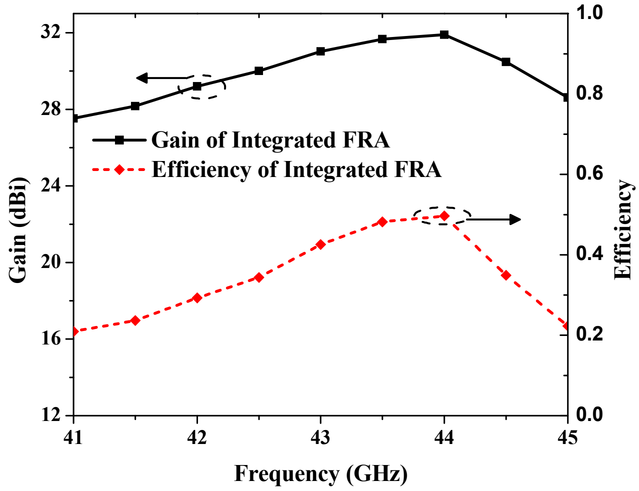


Fig. 4 Measured gain and efficiency of the proposed integrated FRA.

3. Integrated Transmitarray

Similar to reflectarray, transmitarray provides another solution to design high gain antenna in mmW band, and the scheme of integration design, as mentioned in previous, can also be adopted for transmitarray. Fig. 4 shows the scheme of the proposed integrated transmitarray: a planar feed is used as the primary source, and the planar transmitarray is placed with a distance of focus length to its feeding source. By introducing this type of integration design, it is easily to realize circular polarization performance and has no aperture blocking when comparing with FRA. Obviously, this kind of integrated transmitarray, as well, features reduced size, low cost, easy fabrication, high density integration ability and etc.

A transmitarray composed of the patch-loop unit-cell has been designed with a integrated SIW slot array antenna which is similar with the feed antenna used in above FRA. The design transmitarray comprises 4-layer and each layer is the same, as illustrated in Fig.6. The proposed integrated transmitarray antenna has also been exemplified in mmW band, and a peak gain around 33 dBi can be achieved, as shown in Fig. 7.

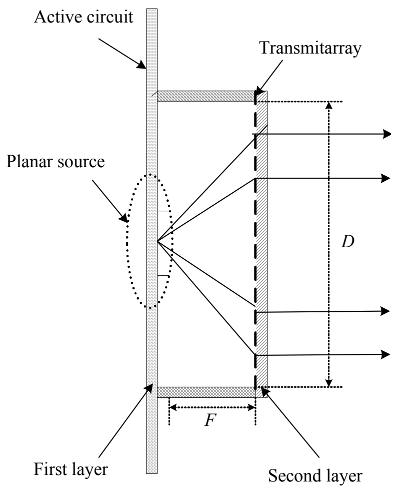


Fig. 5 Geometry of integrated transmitarray antenna.

Fig. 6 Transmitarray composed patch-loop element.

4. Conclusion

In this paper, the integrated reflectarray and transmitarray have been introduced and discussed. Although the detailed design method is omitted in this paper, it should be noticed that the scheme and geometry of these proposed antennas have been well described. The proposed integrated designs have several important merits, such as, low profile, low cost, easy fabrication, and the ability of directly integrated with RF circuits. The introduced concept is very promising for mmW band applications.

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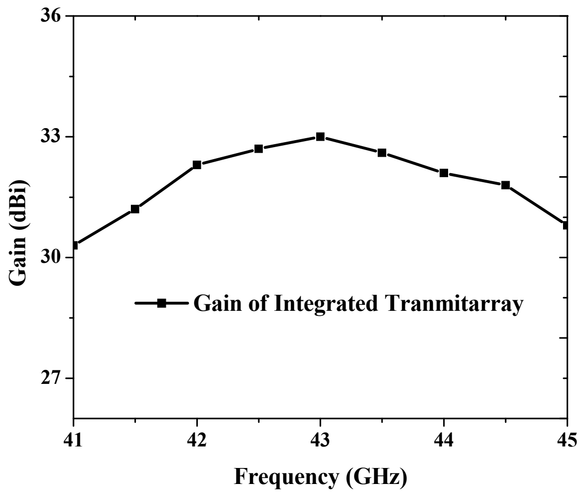

Fig. 7 Gain of the proposed integrated transmitarray antenna.

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