A Coaxial Corrugated Dual-Band Horn Feed

Qiang Zhang, Cheng-Wei Yuan, and Lie Liu

***Abstract*—A compact corrugated dual-band horn feed with high power handling capacity is proposed in this letter. It is composed of an inner choke horn and an outer choke antenna, which consists of the concatenation of a corrugated circular waveguide together with a choke antenna and a spherical cover. Using mode matching theory to determine the scatter matrix of the feed, the analysis allows the return loss and transmission coefficient of each band to be computed accurately. The feeds' return loss is less than −20 dB, and a good far-field radiation pattern at each band has been achieved. All results are simulated, demonstrating the feasibility of the feed. It is suitable for feeding of prime-focus reflectors in a dual-band high-power microwave (HPM) system in the future.**

***Index Terms*—Compact size, corrugated horn feed, dual-band, high-power microwave (HPM), horizontal and vertical corrugations.**

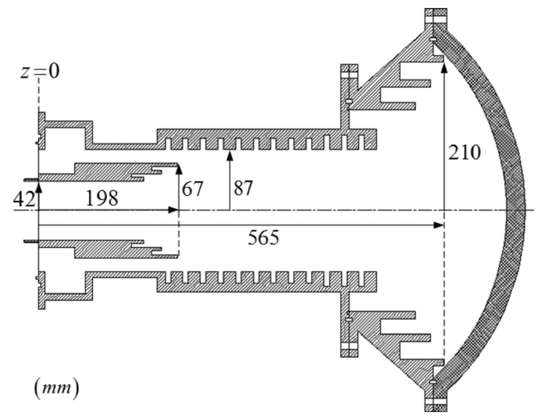

Fig. 1. Cross section of the coaxial dual-band horn feed.

I. Introduction

Radiation system plays an important role in the high-power microwave (HPM) system, which determines whether HPM energy can be utilized effectively. Many radiation systems with different structures have been designed, and some excellent results have been obtained. During recent years, there is so much concern about the threat to electronics imposed by HPM beams with different wavelengths, causing upset and instability in circuits. Thus, different HPM sources have been investigated based on the fast development of pulsed power technologies, and some of them have reached gigawatt output power levels. Furthermore, a new direction for HPM development is to investigate devices capable of producing HPM with two stable and separate frequencies [1]. Therefore, extremely dual-band radiation systems [2], [3] with high power-handling capacity are often required for many current applications. Simultaneous multifrequency functionality at widely separated frequency bands and lower sidelobes within each operating range are the basic requirements to such multiband feeds nowadays, which determine the radiation characteristics of the reflector-type antennas. On the other hand, the overall size of the horn feed is becoming the real key issue in HPM systems at present. Therefore, to design a compact horn feed is another theme for designing a compact radiation system. Obviously, compared to conventional corrugated ones, horn antennas that combine horizontal and vertical corrugations are apparently easier to manufacture, and they also have high performances for stringent applications in a compact size [4], [5].

In this letter, a compact dual-band horn feed with this type of corrugation is introduced, which has high power-handling capacity. It can be used to radiate HPMs with a good far-field radiation pattern at each band, and thus reflector antennas can be utilized effectively. In addition, the horn feed is simple to manufacture. The optimization has been achieved by mode matching method, and the results are confirmed by numerical simulations.

II. Design and Feed Performance

The horn feed, which consists of a series of discontinuities, is fed by a coaxial waveguide at L-band and a circular waveguide at C-band. This structure opens the design possibilities to obtain good radiation characteristics at dual-band with a reasonable size. The coaxial and circular waveguides are stimulated by the TE_{11} mode and connected to the corrugated section as shown in Fig. 1, thus the selected parameters are listed as:

— first, the inner choke horn design;[6].
— second, the outer choke horn design;
— third, the corrugated cylindrical waveguide design;
— fourth, the return loss matching technique.

Considering its special structure, we can use mode matching theory [7] to obtain the overall scatter matrix from which to determine the propagation properties of the feed, progressively cascading the scatter matrix of each discontinuity in cross section and each of the short lengths of waveguide in isolation [8], [9]. The analysis allows the return loss and transmission coefficient of each band to be computed accurately. In addition, TE_{1n} and TM_{1n} modes can be excited at each discontinuity in the feed. Using mode expansion technology, we can get the far-field radiation pattern of the feed. Actually, due to the high development of the optimization tools, the optimization focuses on inner

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TABLE I
DIMENSIONS OF THE COAXIAL DUAL-BAND HORN FEED

Parts	Parameters in common	Corrugation number (from throat to aperture)	Depth (mm)	z-location of top of ridges (mm)
Inner horn with horizontal corrugations	d_1=5mm	1	18	150
	d_2=5mm	2	14	175
Circular waveguide with vertical corrugations	d_1=8mm	1~9	15.5	None
	d_2=17mm	10~12	20	None
Outer horn with horizontal corrugations	d_1=10mm	1	39	470
	d_2=25mm	2	50	525
		3	44	547

and outer radius (or depth) of each corrugation as variables in the design process typically.

The whole structure is divided into three parts to avoid using a great deal of time for simulation. First, the inner choke horn is designed to be flare angle-controlled according to [6], and coaxial corrugations are used to reduce the diffraction from the inner horn edge. Second, a circular waveguide with vertical corrugations plays an important part in the dual-band feed. Based on its designed parameters, it is equal to a TE_{11}-to-HE_{11} mode converter at high frequency and a mode limiter at low frequency. Third, the outer choke horn is designed in the same way as the inner choke horn, which should avoid influencing radiation pattern at high frequency and improve azimuthally symmetric output modes at low frequency simultaneously. Dozens of different geometries have been analyzed to reach the final design for the 1.75 and 4.15 GHz central frequency, with the dimensions given in Table I and Fig. 1, where the width of corrugations is d_1 and the thickness of ridges between them is d_2. Considering its application in the system of HPM, a spherical cover is utilized to airproof the horn feed, thus the power-handling capacity can be improved after the feed is pumped into high vacuum state. At last, the whole system structure is less than φ 50 cm $\times$ 70 cm.

Fig. 2 shows the simulated radiation patterns of the feed at each central frequency for different cut-planes. Relative to the maximum gain possible, the L-band transmit gain is only lower by 0.1 dB than C-band. Furthermore, it can be seen that the compact horn feed has very low sidelobes (lower than -40 dB), and its cross-polar level is of -30 dB. Although we do not care so much about cross-polar level in HPM applications, this parameter can also be improved for future designs. Fig. 3 presents the reflection of the feed at each band. Around the frequency of 1.75 GHz at L-band, the reflection is very low, owing to a simple discontinuity designed in coaxial waveguide, and a more sophisticated matching technique could be used to widen the frequency bandwidths. Over the frequency range of 4.0 to 4.3 GHz at C-band, the reflection is less than -15 dB, with which one can obtain that the radiation efficiency of the feed is more than 95%. The phase center of each band has been calculated from the radiation field, and the phase center is located within $\mathrm{z} = 48 \pm 1.5$ cm over the dual-band. It can be seen that the performance achieved by this new design technique are fairly high, which is especially significant for the higher levels of performance of horn feeds in millimeter-wave or submillimeter-wave bands.

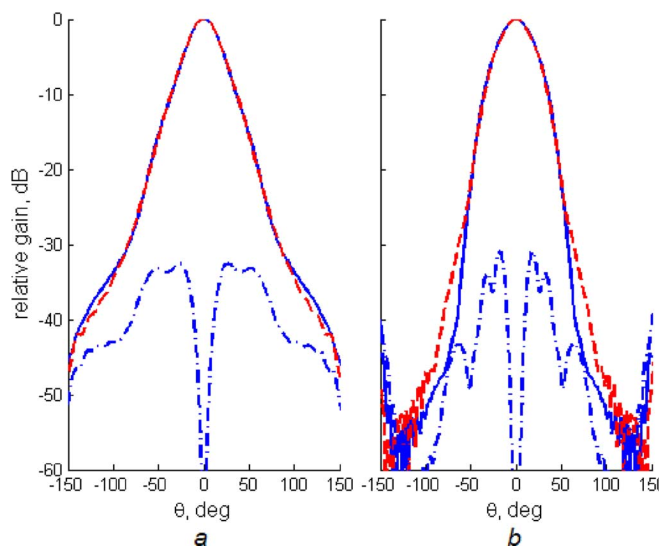

Fig. 2. Simulated results of the horn feed. (a) 1.75 GHz. (b) 4.15 GHz. Solid lines and dashed lines denote far-field radiation patterns at center frequency in E-plane and H-plane, respectively. Dash-dotted lines indicate cross-polar pattern in the 45° plane.

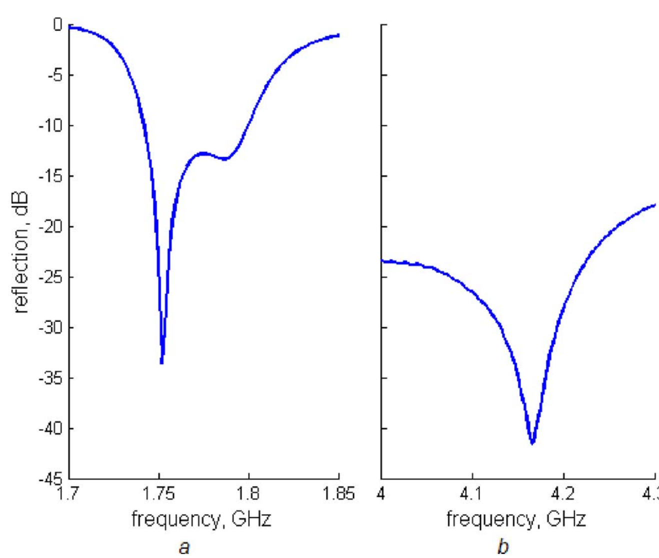

Fig. 3. Reflection of the horn feed against frequency. (a) L-band. (b) C-band.

In order to verify the feasibility of the dual-band horn feed while driving the main reflector-type antenna, the designed feed is planned to be applied in a dual-band radiation system in the

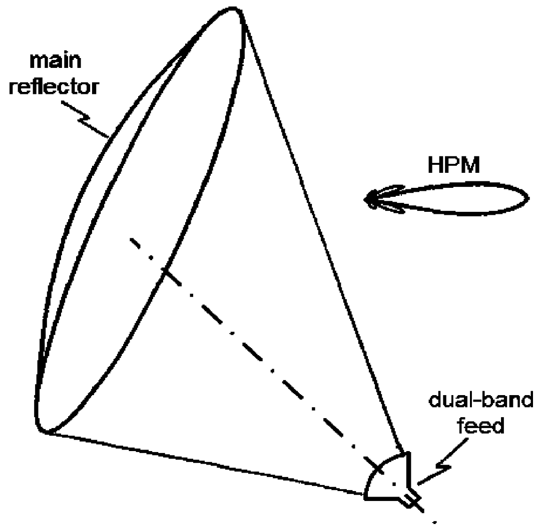

Fig. 4. HPM reflector antenna geometry: An offset shaped single- reflector antenna fed by the corrugated dual-band horn feed.

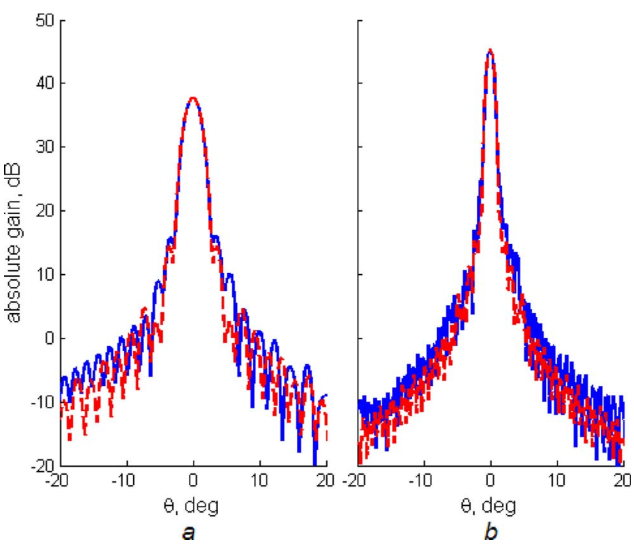

Fig. 5. Far-field radiation patterns of the dual-band horn fed antenna using paraboloidal main reflector. (a) 1.75 GHz. (b) 4.15 GHz. Solid lines and dashed lines denote far-field radiation patterns at center frequency in E-plane and H-plane, respectively.

future, which is composed of the dual-band feed and a reflector, as shown in Fig. 4. An offset-shaped single-reflector antenna with subtended half-angle equaling 32° was designed, and the aperture diameter of the main reflector is 500 cm. Far-field radiation patterns of each band are plotted in Fig. 5. As can be seen, the absolute gain has reached 37.68 dB at 1.75 GHz and 45.48 dB at 4.15 GHz, respectively, which means that its aperture efficiency has reached as high as 69.81% and 74.80%, respectively.

III. CONCLUSION

A compact coaxial dual-band horn feed combining horizontal and vertical corrugations has been designed. The feed's far-field radiation patterns belonging to different bands have been confirmed by numerical simulation, respectively. In addition, the feed with high power-handling capacity provides convenient manufacturing, and it can be applied into dual-band HPM system.

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