

A Novel Dual-Band Dual-Polarized Ortho-Mode Transducer

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Abstract—A novel ortho-mode transducer (OMT) for dual-band dual-polarized communication systems is proposed in this letter. The OMT is loaded with five posts in reasonable positions of the waveguides and a shorted circuit piston in the branch waveguide. Compared with the septum loaded traditional one, the presented OMT is more flexible, simple and easy to fabricate. Both simulations and measurements indicate that the impedance bandwidths of $VSWR < 1.15$ ranging from 6.50 to 7.20 GHz and 8.80 to 10.2 GHz can be obtained. The low insertion losses indicate that the presented OMT can be used in actual project. Moreover, good isolation performance between the two input ports in both bands are obtained because of the inherent existence of cross polarization.

1. INTRODUCTION

The ortho-mode transducers for two orthogonal polarizations are important components in satellite communication systems. The OMT can be treated as a separate or mixture device by separating orthogonal polarizations into different ports and mixing two different orthogonal linearly polarized channels coming from two different ports into a common port [1]. Two separated and isolated signals can be transmitted to antenna system for expanding the capacity within the same frequency. Meanwhile, when signals operating over two different frequency bands, the OMT is of great isolation between the two input channels.

Shown three physical ports, the OMT is a four-port device in electrical field. The common port, usually a waveguide with a square or circular cross-section, provides two electrical ports that correspond to the independent orthogonally polarized signals [2]. The other two ports are constituted by standard or coaxial waveguide ports only conveying the fundamental mode. The ortho-mode transducer can achieve duplex transmission of orthogonally polarized signals in the front end of antenna feed system. It has a direct impact on the overall system performance.

Due to different requirements, there are a number of OMT design solutions [1–5]. The classification is designed mainly based on bandwidth, isolation between polarizations, and other electrical and mechanical aspects [3]. Single septum is used in the traditional OMT, which acts as a shorted circuit piston and ensures high isolation of the orthogonally polarized signals. To solve the drawback of long septum [4], the OMT with double-septum that contributes to reduce the size is proposed. Meanwhile, it can facilitate the matching of the horizontal polarization between the lateral and common ports [1]. To improve the isolation at the Rx port, an irregularly shaped diaphragm is proposed in [5]. However, the thickness of the diaphragm is only 0.5 mm, thus the diaphragm is easily distorted when processed resulting in bad performance of the OMT.

The detailed analyses and results of a novel dual-band ortho-mode transducer for dual-polarized application are given. The septum in the traditional OMT is replaced with posts, which makes OMT more flexible in geometry. By using equivalent circuit method, more posts are situated at proper places to improve the impedance matching in the two input ports. The results show that the $VSWR < 1.1$ of

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the two input ports with excellent transmission coefficients can be achieved. Good isolation performance between the two input ports are obtained in this letter because the orthogonal modes can provide cross-polarization isolation, and the posts in branch ports can further restrain the transmission of signals between the two input ports.

2. DESIGN CONSIDERATIONS

2.1. The OMT Structure

As shown in Fig. 1, the configuration of the ortho-mode transducer consists of a square waveguide, standard rectangular waveguide, transitional waveguide and impedance matching structure. Port 1 exhibits standard rectangular waveguide WR90 ($a = 22.86$ mm, $b = 10.16$ mm), and port 2 WR137 ($a = 34.85$ mm, $b = 15.80$ mm). They are used as the input ports which transmit two orthogonally polarized signals, respectively. WR137 port mainly transmits horizontally polarized wave in $6.50 \sim 7.20$ GHz (C band), and WR90 port is responsible for the vertically polarized wave in $8.80 \sim 10.20$ GHz (X band). The size of the square waveguide port is 31×31 mm², which is usually chosen according to the size of the horn antenna it is connected to. The straightly gradual waveguide is used as a transitional waveguide between the straight arm and square waveguides due to a lot of advantages, such as simple structure and easy processing. The posts and shorted circuit piston play important roles in achieving impedance matching. Detailed descriptions are presented in Section 2.2.

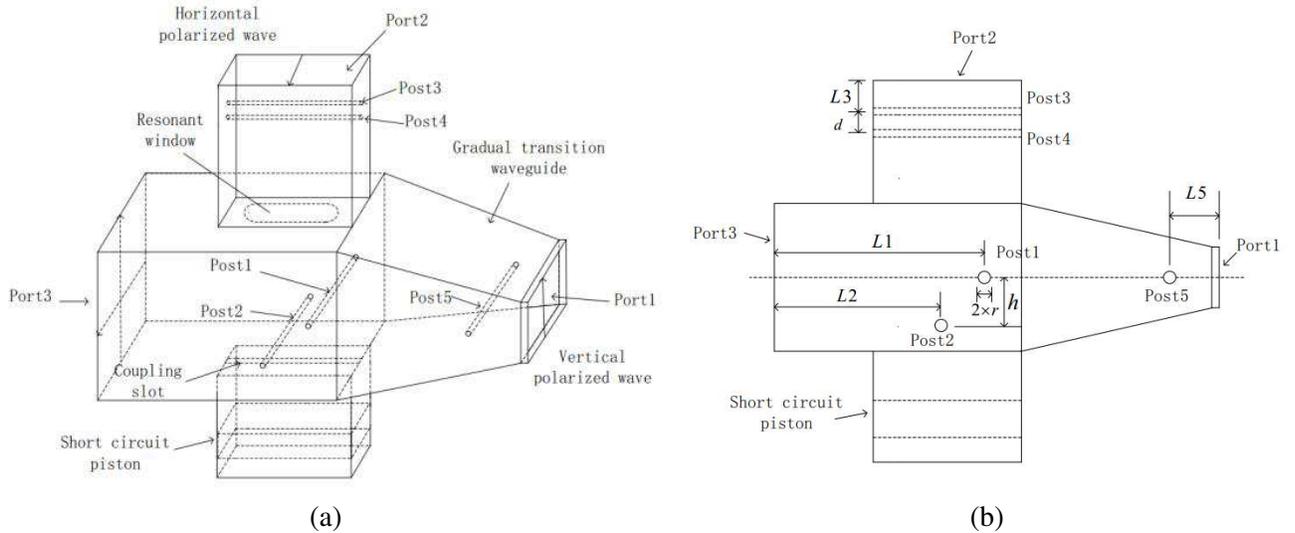


Figure 1. Configuration of the OMT. (a) Solid structure. (b) Planar structure.

2.2. Impedance Matching Structure

This paper focuses mainly on impedance matching properties by using posts and shorted circuit piston. Generally, a post is a thin cylinder that is vertically disposed in the waveguide, and its equivalent reactance is directly affected by diameter size. Based on the equivalent circuit method, the post placed at the broad-side in waveguide can be equivalent to an inductor in parallel. While at the narrow-side, the post can be regarded as a shunted capacitor.

The equivalent circuit of the OMT in the C band is shown in Fig. 2(a). It can be seen that post 1 corresponds to a reactance shunted to the transmission line. With a properly designed dimension, it may obtain an excellent impedance matching. Moreover, it prevents the horizontally polarized wave transmitting to port 1. The effect of post 1 is similar to the septum in the conventional OMT. Then an adjustable shorted circuit piston, which is equivalent to shunting a reactance, is added in front of branch waveguide. The two reactances above can form a resonant circuit for broadening the bandwidth.

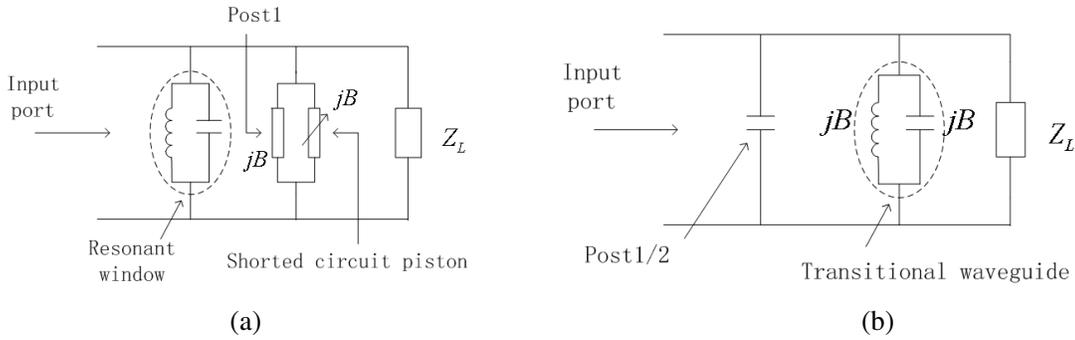


Figure 2. The equivalent circuit of the OMT. (a) The equivalent circuit of the C band (without posts 2/3/4). (b) The equivalent circuit of the X band (without post 5).

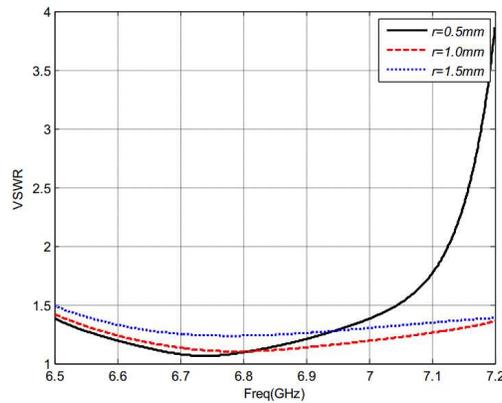


Figure 3. The VSWR of the horizontal polarization with different dimensions of the post 1.

The resonant window is equivalent to a parallel LC resonant network. The signal can be non-reflectively passed through the resonant window when the operating frequency equals the resonant frequency. Actually, it is difficult to achieve this ideal state. Then post 2 corresponding to a reactance connected in parallel is considered for appropriate location to compensate for the impedance mismatch caused by the resonant window. Another two posts are added in the branch waveguide to obtain impedance matching.

Posts 1 and 2 are located in square waveguide. The vertically polarized wave is separated into two parts when passing through posts 1 and 2. Then it can be recombined to continually transmit to the output port. As shown in Fig. 2(b), posts 1 and 2 can be regarded to shunt a capacitor in terms of the vertically polarized wave because the dimensions of the posts cannot be negligible. The straightly gradual waveguide can be equivalent to a parallel LC resonant circuit. The signal can be transmitted to the square waveguide in an ideal state when the size of the transitional waveguide is relatively long. But the straightly gradual waveguide cannot be designed long enough for the requirement of compact size. To solve this problem, post 5 is added in the straightly gradual waveguide. It can not only achieve the matching property of the vertically polarized wave, but also further prevent the transmission between the side wall waveguide and straight wall waveguide.

3. SIMULATED AND MEASURED RESULTS

For an ortho-mode transducer, the main considerations are the impedance matching, insertion loss and isolation properties. The ortho-mode transducer has been simulated and optimized by using CST simulation software. Primary parameters relevant to the reflection coefficient are shown in Fig. 1(b). When only post 1 exists in the OMT, the VSWR of the horizontal polarization with different dimensions

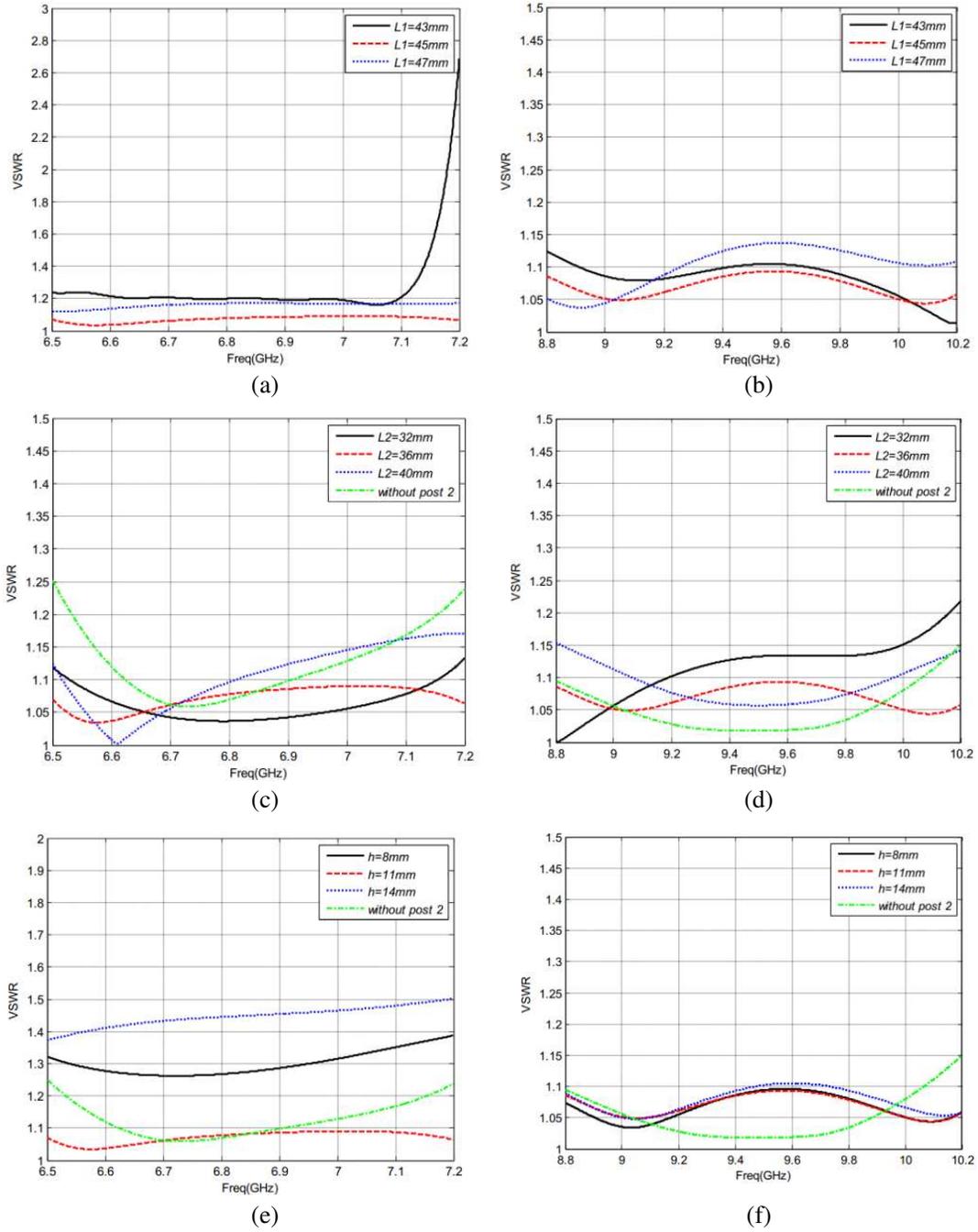


Figure 4. Simulated VSWR of the proposed OMT. (a) Variations in L_1 in C band. (b) Variations in L_1 in X band. (c) Variations in L_2 in C band. (d) Variations in L_2 in X band. (e) Variations in h in C band. (f) Variations in h in X band. ($L_3 = 6\text{ mm}$, $d = 3\text{ mm}$, $L_5 = 13\text{ mm}$).

of post 1 are shown in Fig. 4. It is confirmed that post 1 has a great influence on the impedance matching of the horizontally polarized wave. When parameter r is too small, the VSWR dramatically rises in the high frequency band. As parameter r increases, the VSWR tends to smooth. It exhibits good performance when the radius of the post is selected as 1 mm. To facilitate processing, the specifications of other posts are identical to post 1. The location parameters of posts 1 and 2 are very critical for it may influence the matching properties of the two ports. As the position of the posts changes, the

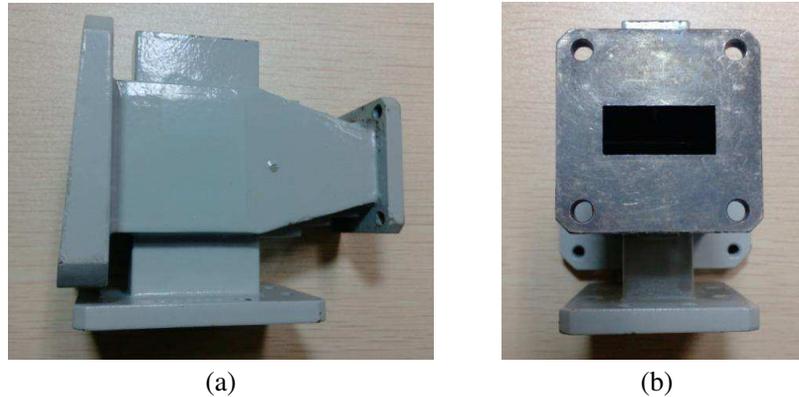


Figure 5. Prototype of the proposed OMT. (a) Side view. (b) Front view.

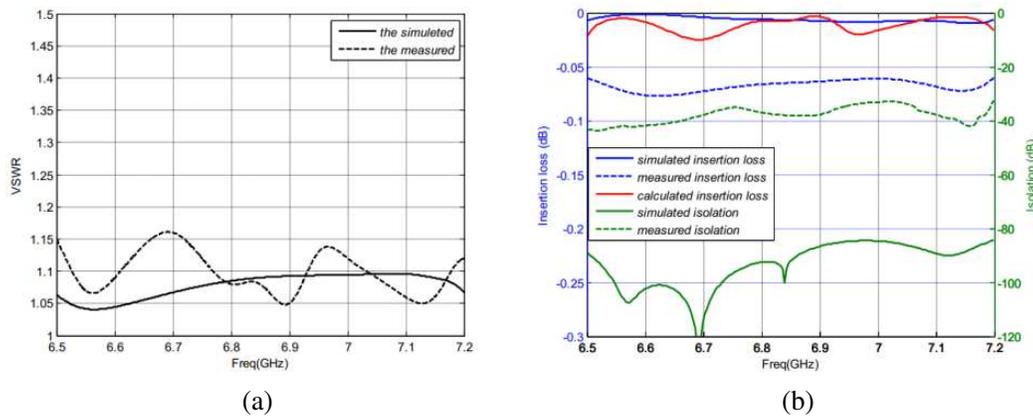


Figure 6. The analysis of C band. (a) The VSWR. (b) The transmission coefficients.

VSWR of the input ports are shown in Fig. 5. It can be seen that the influence of the posts is more obvious on the impedance matching of the horizontally polarized wave than the vertically polarized one. By tuning the positions of posts 3, 4 and 5, optimal results are obtained.

The optimal simulation results of the VSWR, insertion loss and isolation in both bands are shown in Figs. 6 and 7. The impedance bandwidths of $VSWR < 1.1$ ranging from 6.50 to 7.20 GHz and 8.80 to 10.2 GHz can be obtained. The insertion losses are 0.01 dB for horizontal polarization and 0.1 dB for vertical one, respectively. The isolations between the horizontal and vertical ports reach 80 dB from 6.50 to 7.20 GHz and 50 dB from 8.8 to 10.2 GHz, respectively. The isolation in the X band is not high enough because when the vertically polarized wave passes through posts 1 and 2, the horizontal component of electric field will be produced, which may couple to the branch waveguide. The isolation without posts 1 and 2 is shown in Fig. 7(b). It can be seen that the isolation is improved 15 dB over the X band. However, posts 1 and 2 play important roles in achieving matching property. To improve the isolation in X band, an appropriate filter is considered to be added in the branch waveguide.

As shown in Fig. 5, the proposed OMT with finally optimized parameters is fabricated and tested. The total length of the OMT is 92 mm, which is very compact. When measuring the prototype, auxiliary adjusting screws are needed because of the errors caused by fabrication. As shown in Figs. 6(a) and 7(a), the measured impedance bandwidths of $VSWR < 1.15$ ranging from 6.50 to 7.20 GHz and 8.80 to 10.2 GHz can be obtained. The isolations between ports 1 and 2 are also measured, as shown in Figs. 6(b) and 7(b). More than 30 dB isolations are observed between the input ports. They are very different from the simulated ones because the load connected to the port 3 may not be ideal when measured. But they also exhibit good performance. For a three-port network, the insertion loss can be calculated when the reflection coefficient and isolation are given. To verify the accuracy of the

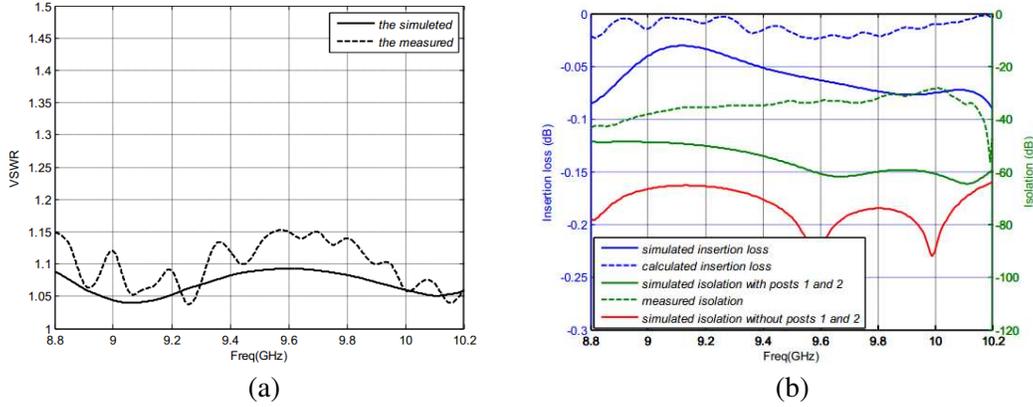


Figure 7. The analysis of X band. (a) The VSWR. (b) The transmission coefficients.

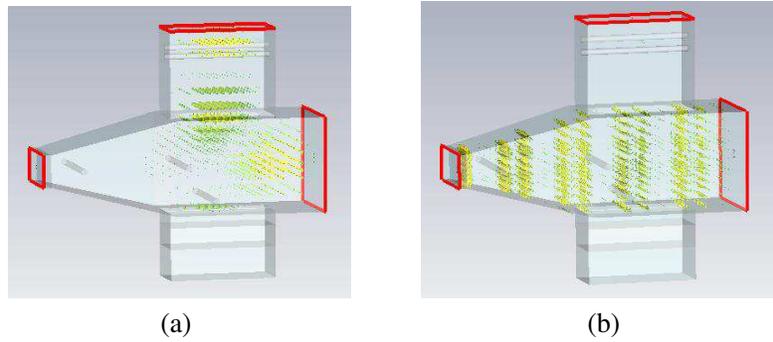


Figure 8. The 3D field distributions of the OMT. (a) C band analysis. (b) X band analysis.

calculated results, the insertion loss in the C band is measured under the condition that two identical OMTs are back-to-back connected at their common waveguide ports. As shown in Fig. 6(b), the measured, simulated and calculated insertion losses in the C band show reasonable agreement except for slight discrepancies. In the X band, only the simulated and calculated results are provided because the existence of two transitional waveguides in back-to-back structure will stimulate more high-order modes, which will restrain the transmission of the main mode and generate oscillation. Based on the results in the C band, the calculated result can perfectly show the insertion loss performance. Generally, poor insertion loss is caused by the discontinuity in waveguides, so the OMT with subtle symmetric design can be considered for further improvement of the insertion losses.

When signals are fed by C port and X port, the 3D field distributions at the two center frequencies are shown in Fig. 8, respectively. It can be seen that post 1 can prevent the transmission between the two input ports. The posts added in the branch waveguide have no effects on the straight wall waveguide, so does the post in straightly gradual waveguide. In other words, the matching designs of two ports are independent of each other.

4. CONCLUSION

The OMT introduces a post, which takes the place of the septum in the traditional one, for simplifying its structure and being easily processing. Through equivalent circuit method, the impedance matching property can be greatly improved by only using more posts. In addition, a shorted circuit piston is added at the opposite lateral port to broaden the bandwidth in the C band. Both simulations and measurements demonstrate that the proposed OMT with simple and compact structure can achieve reasonable performance including low VSWR, low insertion loss and good isolation, over the given frequency bands. The proposed dual-band dual-polarized OMT can easily find its applications in wireless communication systems.

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