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DUAL-BAND ORTHO-MODE TRANSDUCER WITH IRREGULARLY SHAPED DIAPHRAGM

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Abstract—A compact dual-band ortho-mode transducer is presented in this paper. Two orthogonally polarized signals received by a square waveguide are separated into two orthogonal channels at 10.7–12.75 GHz and 10.3–11.9 GHz, respectively, while a single-polarized signal is transmitted at 14–14.5 GHz. To obtain good isolation between the transmit (Tx) and receive (Rx) channels of the same polarization with a compact size, an irregularly shaped diaphragm is proposed as a compact dual-function resonator, which has one transmission zero at the Tx band and one pole at the Rx band. The designed OMT is fabricated and measured in a back-to-back configuration. Measured results agree very well with simulated ones and the isolation improvement by the diaphragm is about 15 dB, which verifies our design.

1. INTRODUCTION

Ortho-mode transducers (OMTs) are widely used in antenna feed systems when dual polarizations are involved [1]. They are usually used to receive dual-polarized signals from a horn antenna and separate them into two independent ports. To realize wide-band performance, symmetrical structures are usually employed, such as Bϕifot junction and turnstile junction [1–3]. Recently, with the growth of communication applications, it is preferred to receive and transmit orthogonally polarized signals simultaneously through a single antenna,

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which covers more than one frequency band. Therefore, dual- or multi-band OMTs are desirable.

Several dual-band and even multi-band OMTs were reported in the past [4–9]. In [4, 5], two orthogonally polarized signals are separated at two different frequency bands. Therefore, they are still physically three-port networks. In practical dual-band dual-polarized antenna feed systems [1, 6, 7], it is more common to receive and separate dual-polarized signals at one frequency band, and transmit single-polarized signals at another frequency band. Therefore, it is physically a four-port network [1]. The design of these dual-band OMTs is usually complicated because they should separate multiple channels both in polarizations and frequency bands. Although there are usually wide guard bands between the operating frequency bands [1], additional filtering elements are commonly required to achieve good isolation between them, especially for those operating in transmit and receive (Tx/Rx) modes simultaneously. Recently, a dual-band OMT operating at 30/44 GHz was designed in [10], which employed a series of stacked irises as a compact filtering element to improve the isolation.

In this paper, a compact dual-band OMT operating in both transmit and receive (Tx/Rx) modes is designed. Two orthogonally polarized signals are received and separated at 10.7–12.75 GHz and 10.3–11.9 GHz, respectively, and a single-polarized signal is transmitted at 14–14.5 GHz. Compared to those in [1, 10], all the Tx and Rx channels are operated at the same Ku-band, which are not widely separated. To obtain a good isolation between the Tx and Rx signals of the same polarization, an irregularly shaped diaphragm is proposed as a compact dual-function filtering element, which presents one transmission pole in the Rx band and one transmission zero in the Tx band.

The designed OMT is fabricated as a monoblock with a thin stacked diaphragm, which is compact, stable, and suitable for mass production. Measured results of our fabricated OMT verify our design concept.

2. DESIGN OF THE DUAL-BAND OMT

In the design of OMTs, a square waveguide supporting dual polarizations is usually used as the common waveguide, and two rectangular waveguides can be connected to extract two orthogonally polarized signals, respectively. For our dual-band Tx/Rx OMT, one more rectangular waveguide port should be connected to transmit the single-polarized signal to the square waveguide port at a higher frequency band. In this case, the isolation between this additional Tx port and the Rx ones becomes a very critical problem. Because the Tx signal is very strong compared to the Rx one and poor isolation of the Tx signal may break down the sensitive Rx channel. Unfortunately, at least one Rx port are of the same polarization of the Tx one, so that they cannot be isolated by the orthogonality of polarization. Therefore, additional filtering elements are required. For the Tx port, a waveguide with reduced cross-section is commonly employed to stop the propagation of waves at the lower frequency [10]. For the Rx port, a bandpass or lowpass filter is usually connected afterward.

2.1. Irregularly Shaped Diaphragm

In our design, an irregularly shaped diaphragm is proposed to improve the isolation at the Rx port, as illustrated in Fig. 1. It is well-known that a rectangular diaphragm and coupling slot in the waveguide can be inductive or capacitive [11] and diaphragms or posts of partial height in

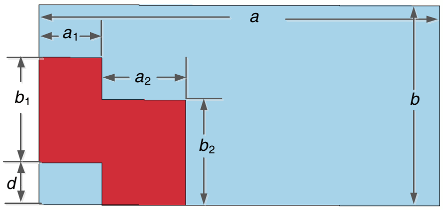


Figure 1. Structure of our proposed irregularly shaped diaphragm.

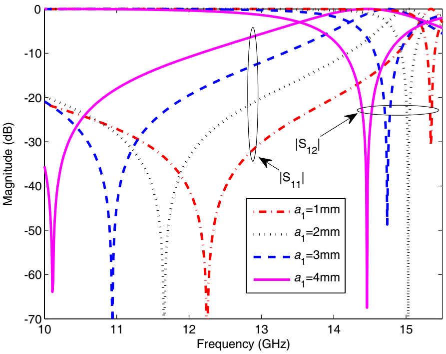


Figure 2. Reflection and transmission responses of our proposed diaphragm with different values of a_1. ($a = 19.1\,\mathrm{mm}$, $b = 9.5\,\mathrm{mm}$, $a_2 = 4\,\mathrm{mm}$, $b_1 = 5\,\mathrm{mm}$, $b_2 = 5\,\mathrm{mm}$, $d = 2\,\mathrm{mm}$.

the waveguide can be resonant structures [12]. Our irregularly shaped diaphragm can be considered as a combination of the regular inductive and capacitive ones. With a properly designed dimensions, it may has one transmission zero as well as one transmission pole, as shown in Fig. 2. This characteristic is very useful in the design of our dual-band OMT, which passes through the Rx signal and rejects the Tx signal.

2.2. Structure of Dual-band OMT

The whole structure of our proposed dual-band OMT is shown in Fig. 3 [13]. Port 1 is a dual-mode square waveguide connected to a horn antenna, Port 2 is connected to the single-polarized Tx channel, and Ports 3 & 4 are connected to two orthogonally polarized Rx channels, respectively. Two rectangular slots are employed to optimize the couplings between the common and branch waveguides. The common waveguide is narrowed in the horizontal direction immediately after the vertically polarized Rx signals are extracted into Port 4. In this way, the propagation of the vertically polarized Rx signals can be stopped before it reaches Port 2, while the horizontally polarized Rx signals can still propagate and reach Port 3. Some step transitions at the Tx port are employed to match the impedance. The proposed irregularly shaped diaphragm is inserted in Port 4.

The proposed OMT without diaphragm is a regular waveguide structure, which can be analyzed by the efficient mode-matching method first to obtain good reflection and transmission performance. And the irregularly shaped diaphragm can be analyzed by Ansoft's High Frequency Structure Simulator (HFSS) to place the transmission pole and zero at proper frequencies. The two parts are then cascaded by their scattering matrices, and the dimensions of the diaphragm and coupling slot at Port 4 are further optimized for better transmission and isolation. The whole structure is slightly tuned by HFSS to finalize the design.

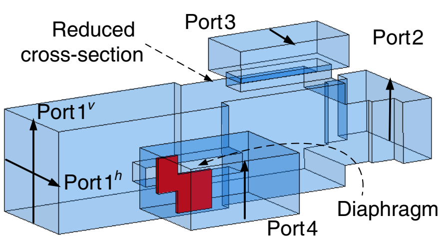


Figure 3. Structure of the proposed dual band Tx/Rx OMT with an irregularly shaped diaphragm inserted.

3. MEASURED RESULTS

The designed OMT is fabricated, and one piece of the irregularly shaped diaphragm is mounted on the top of the vertically polarized Rx port, as shown in Fig. 5. The size of the square waveguide port is $16 \times 16\,\text{mm}^2$, which is usually chosen according to the size of the horn antenna it is connected to. The three rectangular ports are the standard waveguide WR75 ($a = 22.86\,\text{mm}$, $b = 10.16\,\text{mm}$). The optimized dimensions of the diaphragm is $a_1 = d = 3.5\,\text{mm}$, $b_1 = 5.5\,\text{mm}$, $a_2 = b_2 = 6\,\text{mm}$. The thickness of the diaphragm is 0.5 mm, and the total length of the OMT is 89.8 mm, which is very compact. Simulated results are plotted in Fig. 4. For the Tx Port 2, the return loss is better than 15 dB from 13.8 GHz to 15 GHz. For the

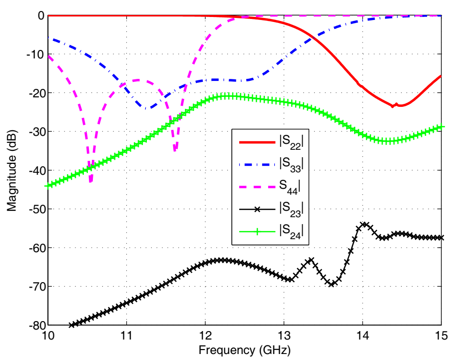


Figure 4. Simulated results of the designed compact dual-band OMT.

Figure 5. Photo of the fabricated OMT with an irregularly shaped diaphragm.

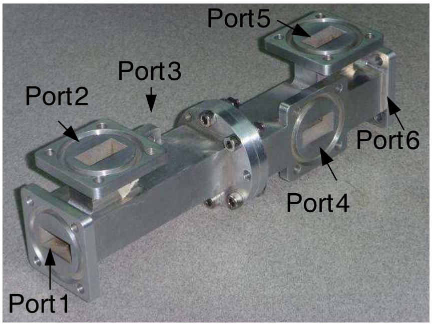
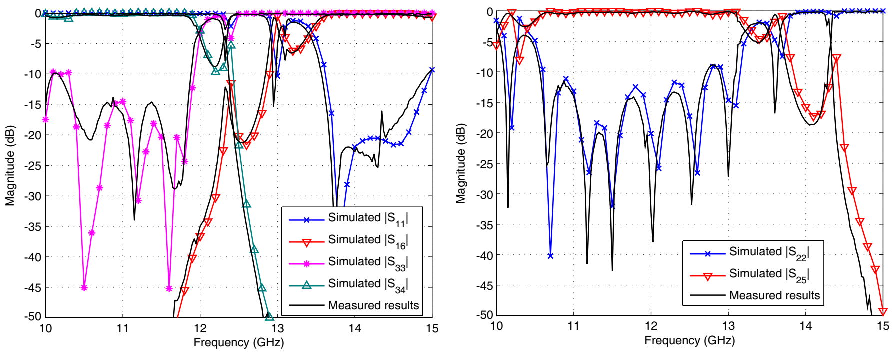


Figure 6. Back-to-back configuration of two identical OMTs.

horizontal-polarized Rx Port 3, the return loss is better than 15 dB from 10.8 GHz to 12.8 GHz. For the vertical-polarized Rx Port 4, the return loss is better than 15 dB from 10.2 GHz to 11.9 GHz.

For the ease of measurement, two identical OMTs are back-to-back connected at their common square waveguide ports, and their port numbers are redefined as indicated in Fig. 6. Measured results of our fabricated OMT exhibit good performance and agree very well with simulated ones, as shown in Fig. 7. Measured back-to-back insertion losses are shown in Fig. 8. For the Tx band from 14 GHz to 14.5 GHz, the return loss is better than 15 dB, and the back-to-back insertion loss is less than 0.4 dB. For the Rx signals, the back-to-back insertion loss between the horizontally polarized ports is less than 0.55 dB



(a) (b)

Figure 7. Back-to-back transmission and reflection coefficients: (a) vertical polarization, (b) horizontal polarization.

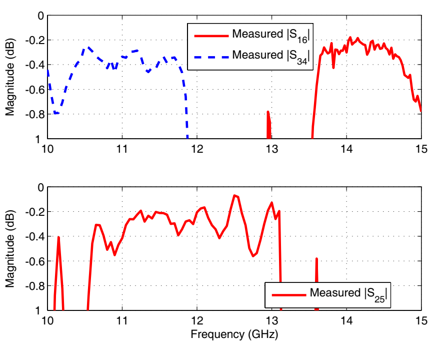


Figure 8. Measured insertion loss.

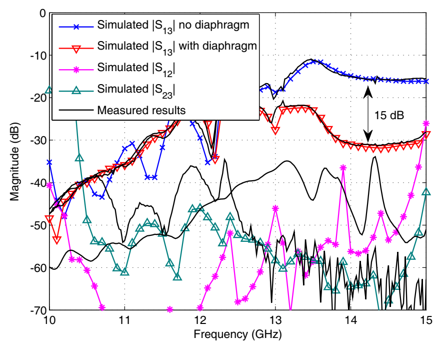


Figure 9. Simulated and measured isolation.

from 10.7 GHz to 12.75 GHz, the back-to-back insertion loss between the vertically polarized ports is less than 0.62 dB from 10.3 GHz to 11.9 GHz. Compared with simulated response of a single OMT shown in Fig. 4, parasitic resonance is observed at around 14.5 GHz in Fig. 7, which is caused by the back-to-back configuration.

The isolation between Ports 1, 2 and 3 is also measured, as shown in Fig. 9. Over 30 dB isolation is observed between Port 2 and other two ports. With the presence of our proposed diaphragm, the isolation between Ports 1 and 3 is improved from 15 dB to 30 dB over the Tx band from 14 GHz to 14.5 GHz.

The thin diaphragm, as shown in Fig. 5, is fabricated separately and stacked on the top of the port, which reduces the fabrication cost. The whole OMT without diaphragm can be fabricated as a single block, which improves the stability.

4. CONCLUSION

A compact dual-band Tx/Rx OMT has been presented, which can receive two orthogonally polarized signals and transmit a single-polarized signal simultaneously. An irregularly shaped diaphragm has been proposed as a compact dual-function filtering element, which forms a transmission zero at the Tx band and a transmission pole at the Rx band. Good isolation between the Tx and Rx ports of the same polarization has, therefore, been obtained with a compact size. The proposed OMT has been implemented at Ku-band and measured results have verified our design.

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