Compact Waveguide Load with Thin Film Resistor

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Abstract— In this paper, we present a compact rectangular waveguide load using tantalum nitride (TaN) thin film resistor (TFR) as an absorber for Ka band applications. The TFR having good temperature coefficient and stable performances is attached on an alumina substrate. It can be easily attached to an end wall of a waveguide for connecting an adjacent waveguide flange. To achieve good impedance matching over a wide frequency range, we put TFR with stepped shape at the center of waveguide. It is designed with an alumina substrate with TaN TFR. The actual size of the 5 mil alumina substrate with sheet resistance of $100\,\Omega$/sq is $3.5\,\mathrm{mm} \times 9.0\,\mathrm{mm}$. Verification of the design results has been carried out by fabrication and measurement of the waveguide load. Return loss above 20.0 dB has been obtained over frequency range of 4.0 GHz in the Ka band.

1. INTRODUCTION

Due to excellent electrical performances such as low insertion loss, high return loss and high power handling capacity, waveguide components are widely adopted for microwave communication systems in spite of a relatively larger volume than microstrip or coaxial components. Waveguide loads are needed for directional couplers used for test set-up and hybrid waveguide couplers to obtain high output power by combining parallel multiple power amplifiers with solid-state devices [1, 2]. Especially, a compact waveguide load is required to develop compact SSPA using hybrid couplers (branch coupler or magic-tee combiner) with matched loads.

Since absorbing material in the waveguide attenuates input RF signal, the shape and the place of absorber depend on electrical performances of loads. In general, gradual increase of absorber makes good impedance matching over a wide bandwidth. The absorber is located at the center of a waveguide where the electric field intensity is the greatest [3].

We proposed a compact rectangular waveguide load using a thin film resistor (TFR) as an absorber. It works by placing a resistor in the center of the waveguide. To make good impedance matching over wide frequency range, we put thin film resistor with stepped shape. Tantalum nitride (TaN) TFR with good temperature coefficient and stable performances is produced on an alumina substrate that shows suitable accuracy of dimension [4]. We designed a compact waveguide load with TaN thin film resistor for Ka band applications. The resistivity is $100\,\Omega$/sq and the height of substrate is 5 mil. The proposed matching termination can be easily attached at the end wall of a waveguide. Thus it can be easily connected to the waveguide flange of a component. Several samples for WR 28 standard waveguide were fabricated and measured to confirm the reproducibility. The actual size of the alumina substrate is $3.5\,\mathrm{mm} \times 9.0\,\mathrm{mm}$. We confirmed that all the results agreed excellently. The measured return loss above 20.0 dB has been obtained over the frequency range 26.5 GHz to 30.5 GHz.

2. DESIGN AND ANALYSIS

2.1. Design of Compact Waveguide Load

Figure 1 shows the structure of the waveguide load with TFR attached on the dielectric substrate in this work. The substrate with TFR is located in the center of waveguide. The substrate which can be easily mounted on the end wall of the waveguide plays a role of supporting the TFR. In order to design the waveguide load, the effect of the dielectric substrate must be considered because the substrate affects the total resistivity.

We choose TaN material and alumina substrate, since the TaN TFR has good temperature coefficient and stable performances, and an alumina substrate shows suitable accuracy of dimension. The impedance matching characteristics depend on the length and the shape of the TFR with the sheet resistance. An easy way to implement a compact waveguide load is to use gradual increasing the width of the film resistor to get good return loss over a wide frequency range. We used multiple sections instead of tapering to avoid sharp edge where the strong electric field occurs. A three-stepped TFR is obtained by compromising between the length of a TFR and return loss. The compact waveguide load with TaN thin film resistor is designed as shown in Figure 2. The

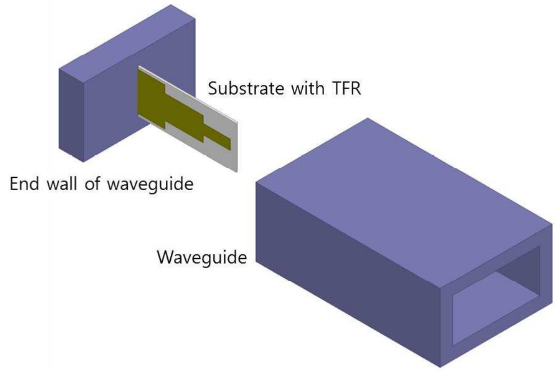
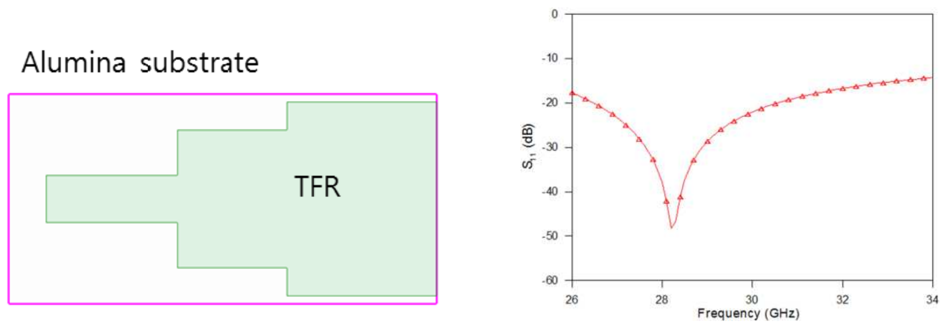
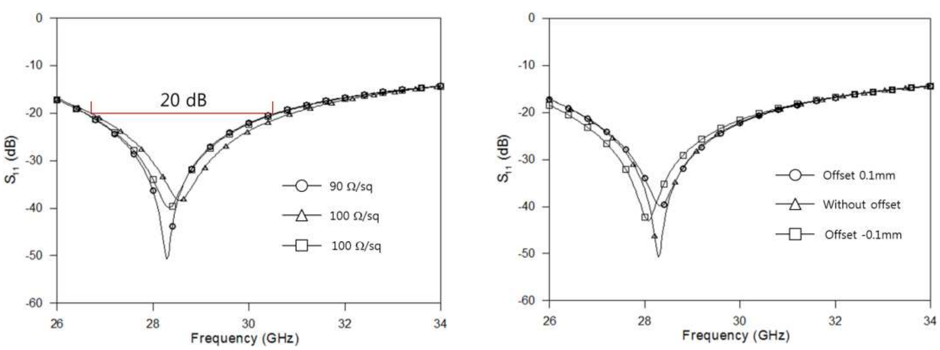


Figure 1: Structure of the proposed waveguide load with thin film resistor.



(a) (b)

Figure 2: (a) The layout of TFR on the alumina substrate. (b) Return loss of the designed waveguide load.



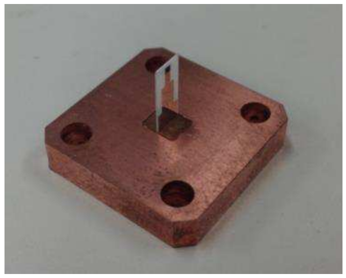
(a) (b)

Figure 3: (a) Return loss according to the variation of $\pm 10\%$ sheet resistance. (b) Return loss according to the variation of ± 0.1mm offset.

resistivity is $100\,\Omega$/sq and the height of substrate is 5 mil. The actual size of the alumina substrate is $3.5\,\mathrm{mm} \times 9.0\,\mathrm{mm}$.

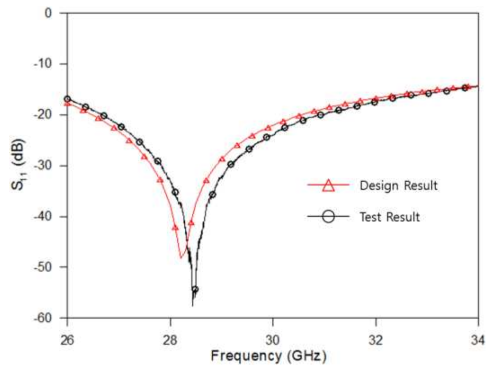
2.2. Sensitivity Analysis

In particular, frequency characteristics may deteriorate due to fabrication error at higher frequency band such as millimeter band. Thus a waveguide load having wideband characteristics while being easily fabricated and assembled is required. Sensitivity analysis is performed according to the fabrication and assembling tolerance such as the variation of sheet resistance and dimension error. Figure 3(a) shows the return loss with respect to the variation of sheet resistance. The sheet resistance can be varied due to fabrication error and variation of temperature. Return loss above 20 dB is maintained over 3.8 GHz range within the variation of $\pm 10\%$ sheet resistance. While assembling alumina substrate with TFR on the end wall of waveguide, the position of longitudinal direction will be changed due to human errors. Figure 3(b) shows the return loss according to the change of position such as ± 0.1 mm offset. Note that the proposed load has stable return loss



(a)

(b)



(c)

Figure 4: (a) Fabricated compact waveguide load. (b) Rectangular waveguide connected with the fabricated load. (c) Design and test results.

characteristics during variation of resistance and dimension error.

3. FABRICATION & MEASUREMENT

Several samples for WR 28 standard waveguide were fabricated and measured to confirm the reproducibility. Figure 4(a) shows the fabricated compact waveguide load composed of an end-wall and an alumina substrate with TFR. As shown in Figure 4(b), the compact load can be easily connected with the standard flange of a rectangular waveguide line. Figure 4(c) shows the simulated and measured results of the designed load. We confirmed that all the results agreed excellently. The measured results have proved the design results, as shown in Figure 4(c). Return loss above 20.0 dB has been obtained over 4.0 GHz of bandwidth in the Ka band.

4. CONCLUSION

In this paper, a compact waveguide load composed of a dielectric substrate with TFR has been proposed. This compact load can be easily fabricated and connected to the waveguide lines. The fabricated load has return loss above 20 dB over the frequency range 26.8 GHz to 30.8 GHz. It can be applied to a waveguide termination for hybrid combiners. For high power applications, the thermal analysis can be followed in the near future.

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