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Ka-band broadband filtering packaging antenna based on through-glass vias (TGVs)

Key words: Filtering packaging antenna (FPA); Through-glass vias (TGVs); 3D packaging devices; Laser bonding

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Motivation

1. The introduction of two band edge absorptive radiation nulls could effectively address the impact of reflected signals in the stopband on the microwave system (power amplifier) while reducing the dimensions and insertion loss.
2. The selected glass packaging material can not only improve the integration of the packaging antenna, but also obtain a relatively good microwave characteristic, such as radiation efficiency and loss.
3. The utilization of low-temperature laser bonding to realize three-layer interconnection is not only suitable for temperature-sensitive materials, but also could effectively reduce the process cost.

Method

Electrical interconnection of this three-layer structure is achieved using laser bonding interconnections.

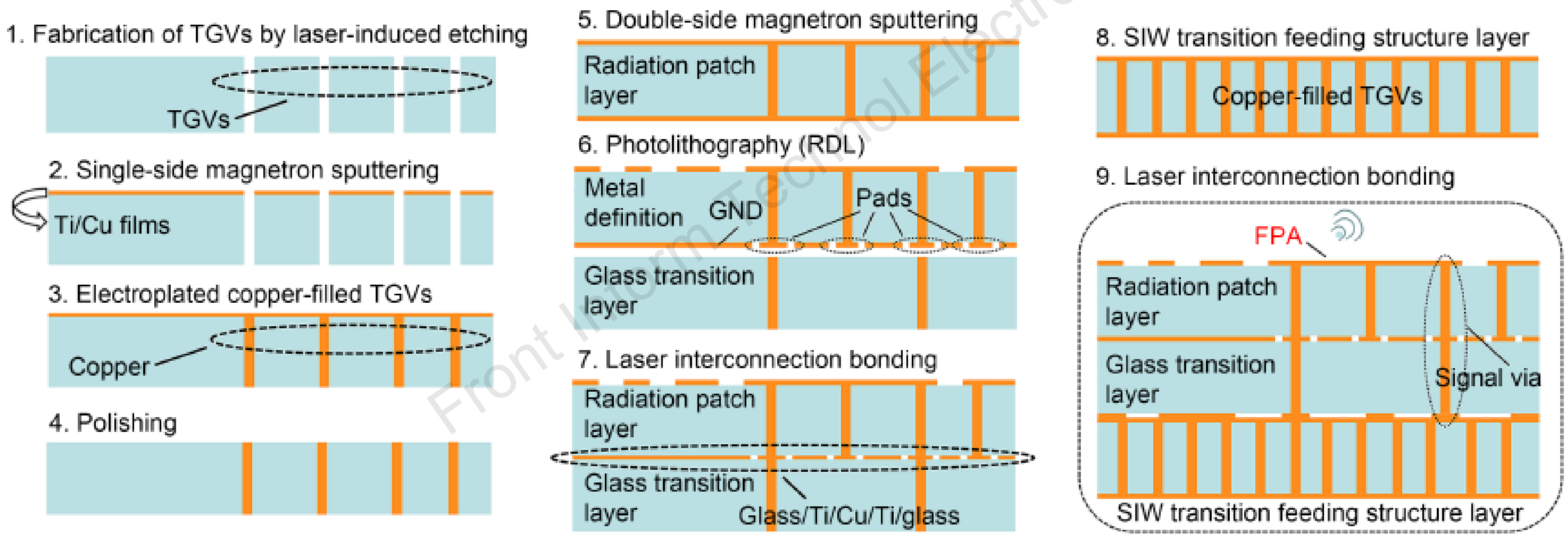


Fig. 2 Fabrication process of the proposed FPA (FPA: filtering packaging antenna; TGV: through-glass via; RDL: redistribution layer; SIW: substrate integrated waveguide)

Method

The destructive superposition of the radiation field from the opposite current gives rise to nulls, and the electromagnetic wave radiated by the main body is in the opposite phase to the electromagnetic wave reflected from the ground, which also produces a destructive superimposed radiation field that is responsible for null 2.

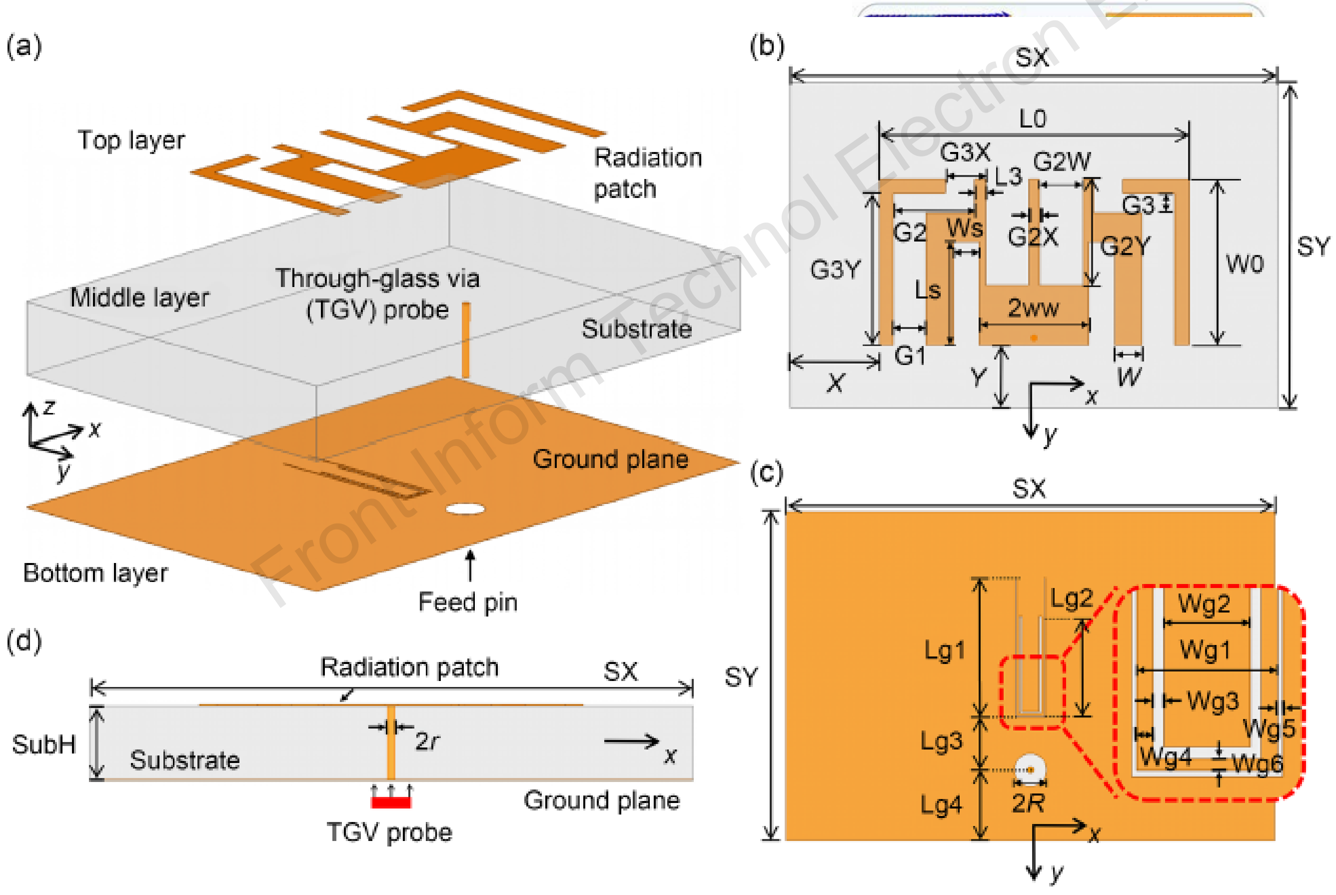


Fig. 3 Geometry of the proposed filtering packaging antenna: (a) exploded view; (b) top view; (c) bottom view; (d) side view

Method

The radiation patch layer provides electrical interconnection to the substrate integrated waveguide (SIW) transition feeding structure layer by a glass transition layer formed by laser bonding process using a pad and a through-glass via (TGV).

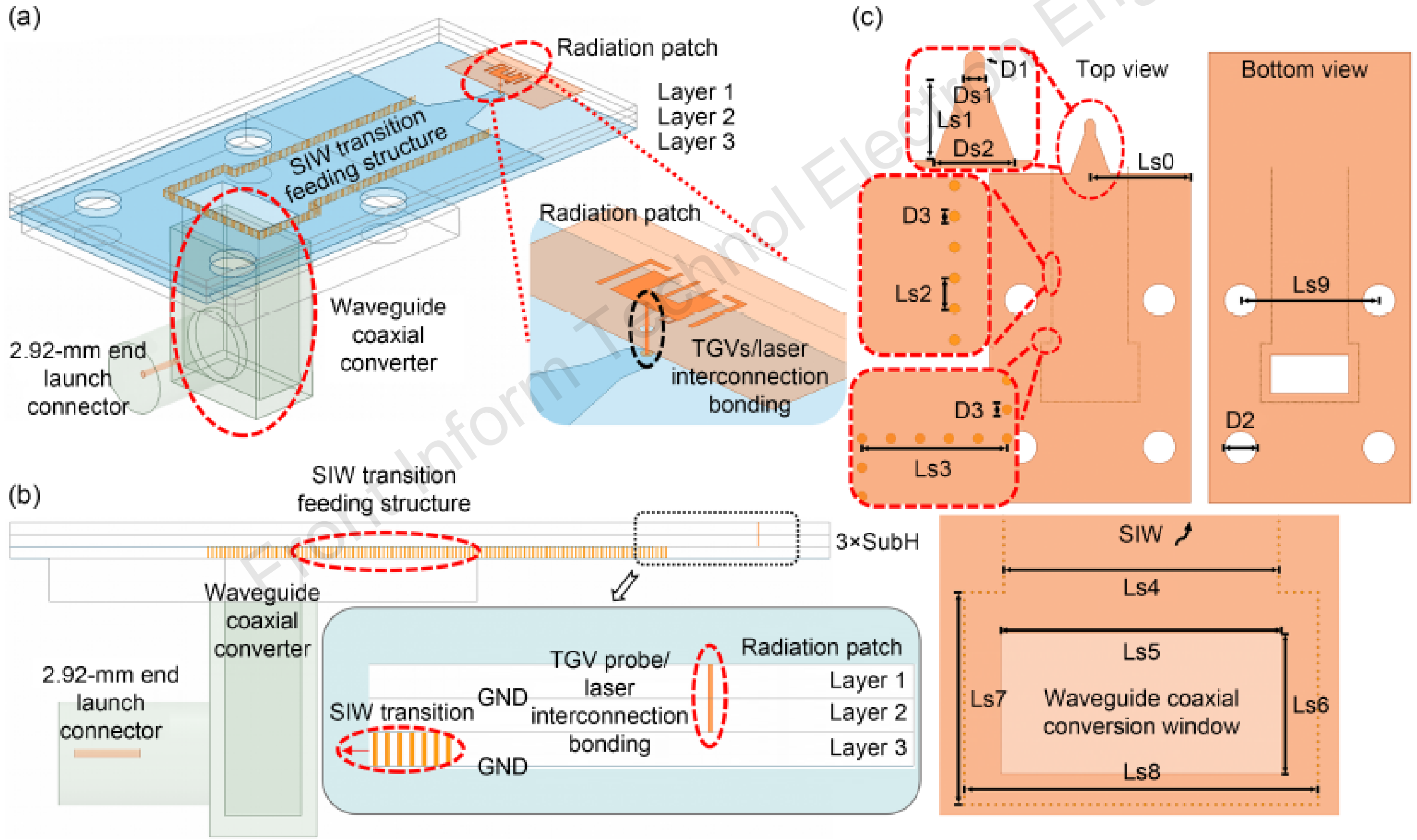


Fig. 4 Geometry of the proposed filtering packaging antenna (FPA) with substrate integrated waveguide (SIW) transition feeding structure: (a) exploded view; (b) side view; (c) SIW transition feeding structure

Method

The proposed filtering packaging antenna (FPA) has four radiation nulls for the band-edge, which improves the suppression level in the stopband. The impedance is matched from 29.4 to 36.4 GHz, with the measurement out-of-band suppression higher than 16.51 and 16.82 dB for the lower and upper stopbands, respectively. The measurement peak realized gain is ~6.5 dBi.

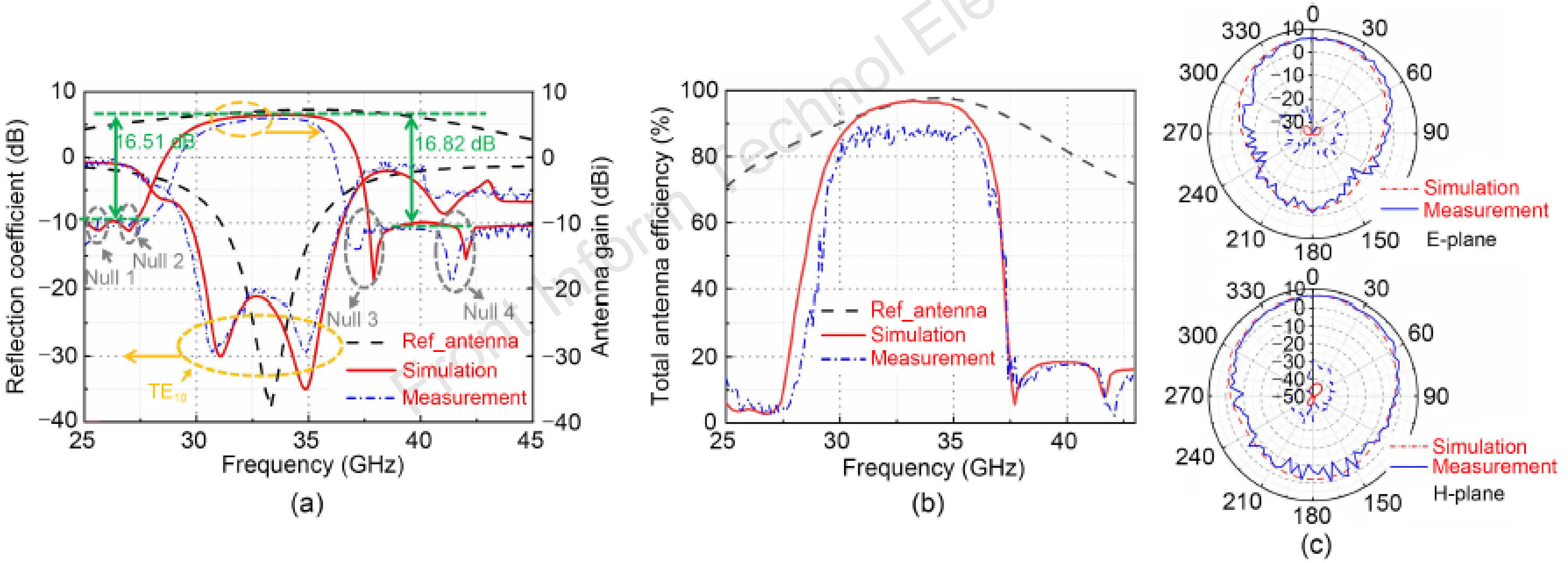


Fig. 11 Measurement and simulation results of reflection coefficient and antenna gain (θ=0°) (a), radiation efficiency (b), and radiation patterns at 33 GHz (c)

Method

As a whole, the FPA is particularly suitable for millimeter-wave communication systems.

Table 3 Comparison with packaging antennas

Reference	Fabrication technology	Integration level	Antenna dimension	Bandwidth	Feed type	Antenna type	Gain (dBi)
Hwang et al., 2017	PCB	Middle	$0.009\lambda_0^3$	9.3%	Coplanar stripline	Yagi-Uda	5.7
El-Halwagy et al., 2018	PCB	Middle	$0.09\lambda_0^3$	25.7%	SIW	SIW dipole	4.5
Yao et al., 2020	Si (WLP)	High	$4.1\lambda_0^3$	28%	Waveguide	Horn	
Watanabe et al., 2020	Glass	High	$0.004\lambda_0^3$	28.2%	TGVs	Yagi-Uda	4.8
Xia et al., 2020	Glass	High	$0.049\lambda_0^3$	33%	CPW-slotline	Taper-slot	3.5
This work	Glass	High	$0.1\lambda_0^3$	21.2%	SIW+TGVs	Filtenna	6.5

λ_0: guide wavelength; PCB: printed circuit board; SIW: substrate integrated waveguide; TGV: through-glass via; CPW: coplanar waveguide

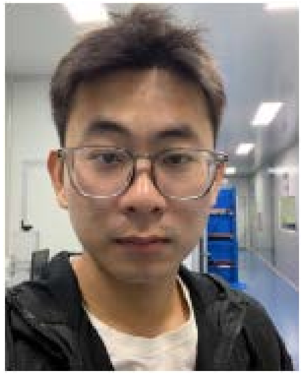
Table 4 Comparison with filtering antennas

Reference	Antenna dimension	Number	Bandwidth	Feed type	Gain (dBi)	Suppression level (dB)	Efficiency (%)
Hu HT et al., 2022	$>0.2864\lambda_0^3$	2	15%	Coupling	7.9	19.1	92
Li JF et al., 2018	$0.021\lambda_0^3$	2	23.5%	Coaxial	6.8	>17	
Jin et al., 2018	$0.012\lambda_0^3$	1	7%	Coaxial	6.6	>11	80
Hu PF et al., 2019	$0.029\lambda_0^3$	2	23.1%	F-shaped probe	8.2	>21	72.7
Liu et al., 2020	$0.0169\lambda_0^3$	1	5.86%	Coaxial	6.28	>17	72.5
Li JF et al., 2021	$0.022\lambda_0^3$	2	19.4%	Coaxial	6	>15	75
Hu KZ et al., 2020	$0.005\lambda_0^3$	1	5.1%	Microstrip	6.3	13	
This work	$0.1\lambda_0^3$	3	21.2%	SIW+TGVs	6.5	>16.5	89.5

λ_0: guide wavelength; number: the number of substrate layers; SIW: substrate integrated waveguide; TGV: through-glass via

Conclusions

1. This work presents an FPA with three layers of glass bonding interconnection and assembly, which is particularly suitable for millimeter-wave receiving or transmitting circuit systems.
2. Glass-based three-dimensional (3D) packaging antenna is a novel laser interconnection bonding scheme to realize a low-cost, high-density 3D interconnected structure.
3. The introduction of four radiation nulls can effectively improve the suppression level in the stopband.



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