Air Gap Coupled Microstrip Antenna for K/Ka Band Wireless Applications

K. S. Ravi Kumar, Yashpal Singh, and K. P. Vinay

Abstract A novel air gap coupled microstrip patch antenna is proposed for K/Ka band wireless applications. The antenna consists of defected ground structure and three-layer stacking of two FR4-epoxy and one air gap with two rectangular patches layered vertically with L-shaped slot. The dimensions of the antenna are 20 × 20 × 4 mm^3. The proposed antenna operates in the frequency ranges of 16.89–33.89 GHz which covers the total K-band (18–26.5 GHz) and partial Ka band (26.5–40 GHz). The designed antenna is simulated by using HFSS EM simulator. The simulation result shows the proposed antenna gain of 9.34 dB and radiation efficiency of 76%.

Keywords DGS · L-shaped patch · FR4-epoxy · Stacking · HFSS software

1 Introduction

Recent studies had provided the clear understanding of importance of antenna in the wireless communication system. So, choosing antenna based on its application is very important, and the other way to get good antenna is to design with compact size, high efficiency, high gain and bandwidth [1].

Today, most of us are using compact mobile devices in our daily life, so the proposed antenna design is to be too compact for fitting in that device. PCB antenna makes most handy devices as they include in the circuit. Patch antenna is one of the PCB antennas which can be used for different applications. The present 5G era operates in the range of 24–30 GHz which comes under K/Ka band, and this K/Ka

K. S. Ravi Kumar (✉) · K. P. Vinay
RAGHU Engineering College, Visakhapatnam 531162, India
e-mail: Srinivas.ravikumar260@gmail.com

K. P. Vinay
e-mail: phanikvinay@gmail.com

Y. Singh
Somany Institute of Technology and Management, Rewari, Haryana, India
e-mail: ypsingh10@rediffmail.com

P. S. R. Chowdary et al. (eds.), *Microelectronics, Electromagnetics and Telecommunications*, Lecture Notes in Electrical Engineering 655,
https://doi.org/10.1007/978-981-15-3828-5_17

band also has applications like multimedia transmission where ultra-wideband is necessary.

This design is focused mainly on ultra-wideband patch antenna operating in K/Ka band to achieve this. There are a lot of techniques used like stacking of patch vertically, introducing air layer between substrate [2], increasing height of substrate, slotted patch [3–5], increasing relative permittivity of substrate material [6], truncated ground plane [7], notches and slits in the ground plane [8] which are for making antenna to operate in K/Ka band, whereas defected ground structures and defected patch [9] are for controlling gain and resonant frequency, and decreasing ε_r of substrate is for increasing bandwidth. As the gain and bandwidth product remains constant for the antenna, any one of the parameters must be compromised to obtain optimized result in terms of gain and bandwidth by combining all the mentioned parametric changes. It is clearly observed from simulation results that the proposed antenna's bandwidth is increased from 8.5 to 17 dB, and gain and radiation efficiency remained satisfactory.

2 Antenna Design

The proposed compact UWB antenna with its dimensions is presented in Fig. 1, it consists of 4 figures where Fig. 1a is the upper patch which contains a rectangular patch with a rectangular slot total patch having width of 1 mm, Fig. 1b consists of lower patch of rectangular shape having L-shaped slot. This is a parasitical patch which is excited by the backward radiation of upper patch. As we are using co-axial feeding for the inner probe of feed that has to travel through lower patch to reach the upper patch, we will make circular slot of radius 0.6 mm at the feed point. Fig. 1c gives us the overview on layered pattern. It consists of three layers FR4-epoxy, air, FR4-epoxy on each FR4-epoxy a patch is fabricated, gives us information about co-axial feeding probe and also consists of two parts co-axial pin and inner probe. Inner probe passes through substrate to reach upper patch, and down the ground plane, co-axial pin consists of one inner and one outer probe, where inner probe is made up of pec having $\varepsilon_r = 1$ material and outer probe is made up of Teflon(tm) having $\varepsilon_r = 2.1$, and the height of inner probe must be taken as such that it just touches the upper patch so it is 4 mm. The radius of inner probe is 0.5 mm and outer probe is 1.66 mm. Fig. 1d gives us how ground has to be defected, and the total figure gives us the design considerations that we had considered.

3 Results and Discussion

The proposed antenna is simulated in HFSS EM simulator, and the following inferences are taken from the obtained results.

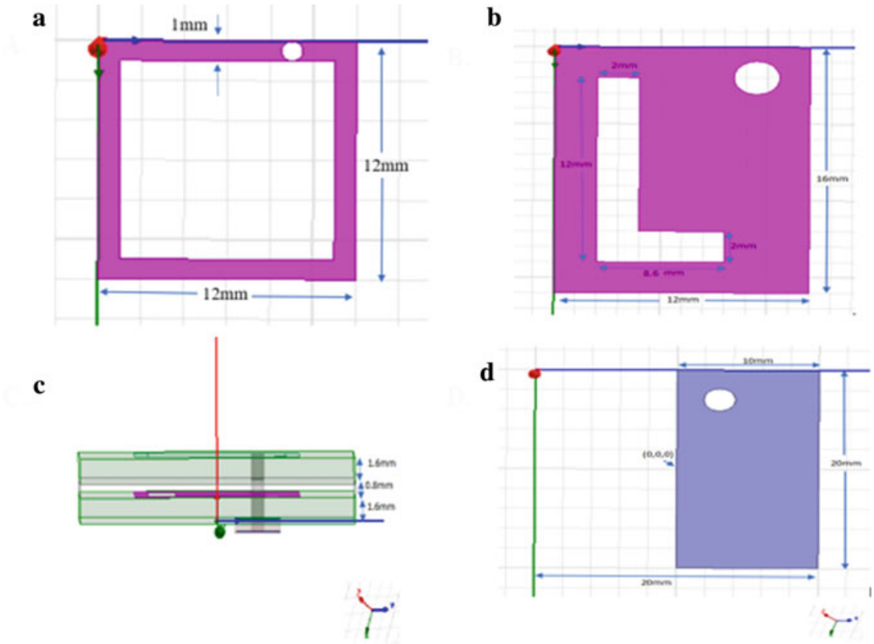

Fig. 1 **a** Upper patch with optimized dimensions layered on substrate with copper. **b** Lower parasitical patch with optimized dimensions. **c** Layered structure of sandwiched air between two substrates. **d** Defected ground structure with feed location (−3, 5.5, 0)

Figure 2a shows the S11 parameters where the range of frequencies that the return losses are less than −10 dB is 16.89–33.8 GHz, so the bandwidth of proposed antenna is 17 GHz which is 50% more than referenced antenna.

Figure 2b is about input impedance of patch antenna for perfect impedance matching with SMA 50 Ω co-axial probe, the input impedance must be 50 Ω in the simulation, and it is 49.98 Ω at 22.7 GHz and 50.19 Ω at 28.7 GHz, so that perfect impedance matching is acquired.

The simulated results of voltage standing wave ratio (VSWR) are shown in Fig. 2c where VSWR < 2 for frequency of operation.

Figure 2d contains the surface current distribution of antenna where the maximum current occurs at the edges of patch, the surface current density at 28.9 GHz is 88.4 A/m and at 22.9 GHz is 78 A/m, and the maximum density is observed at feed location.

Radiation efficiency is an important parameter to decide the antenna efficiency. Fig. 2e shows that the radiation efficiency of our antenna is 76% at 28 GHz which an acceptable value.

Gain, which is important consideration of proposed antenna, is shown in Fig. 2f where the gain is maximum at 31 GHz, i.e., 9.35 db. Gain at the resonating frequency is 8.03 db which is also very high for a patch antenna.

a

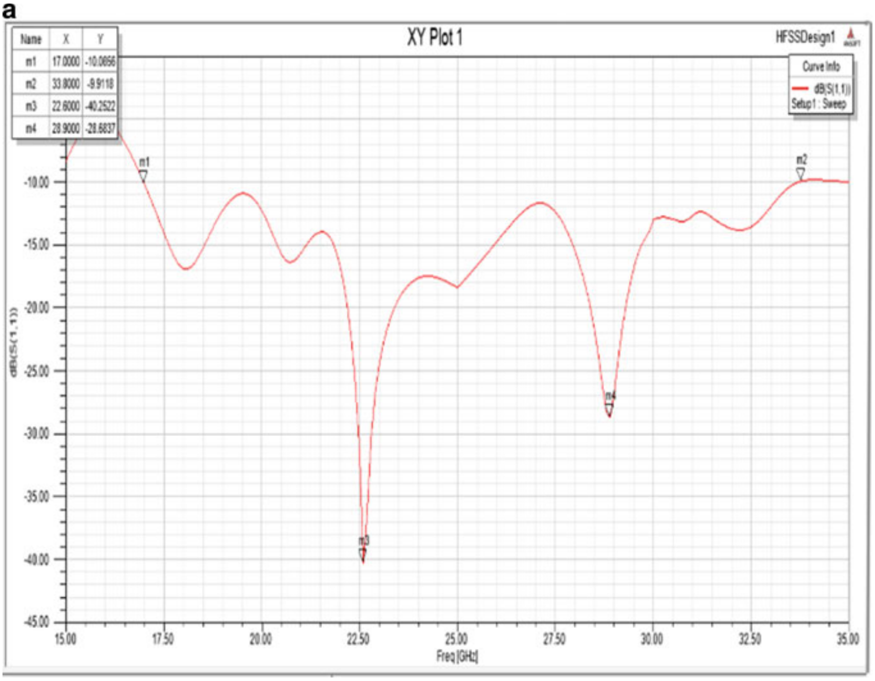

Fig. 2a Simulated return losses showing bandwidth as 17 GHz

b

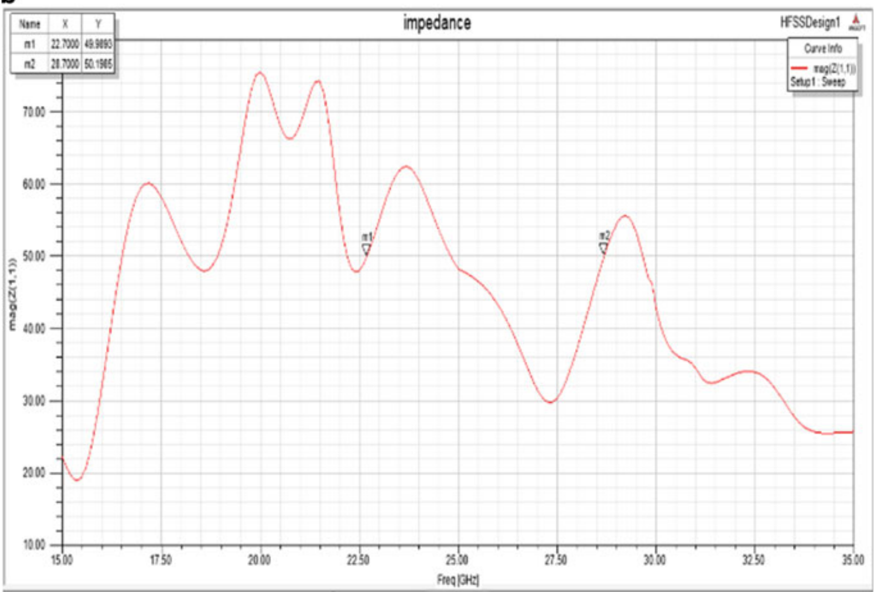

Fig. 2b Simulated result of input impedance (Z11)

c

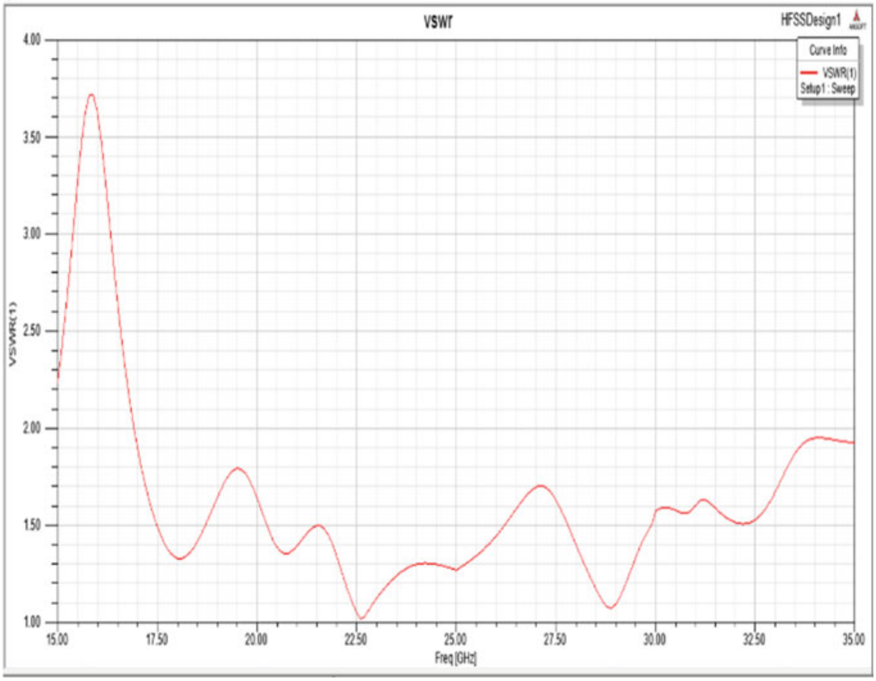

Fig. 2c Simulated graph of VSWR

Radiation pattern which is important to find the beamwidth and directivity is shown in Fig. 2g where only *E*-plane ($\phi = 0°$) and *H*-plane ($\phi = 90°$) at 22.6 GHz is considered. Here, vertical axis represents the gain in dB, and graph shows the beam that radiates with wide beam angle (Table 1).

4 Conclusions

The proposed antenna is having compact size and ultra-wideband characteristics (16.8–33.8 GHz) in K/Ka band. It has a 50% increase of bandwidth (8.5–17 GHz) than another antenna reported in table, and it also has a 1% increase in gain (8.5–9.35 dB). Therefore, the requirement of compact and ultra-wideband antenna has been satisfied. The proposed antenna operates mainly in K/Ka band which can be used for 5G and in the internal communication devices. As the bandwidth is also high, it is also used for in-house communication, RADAR and satellite communication.

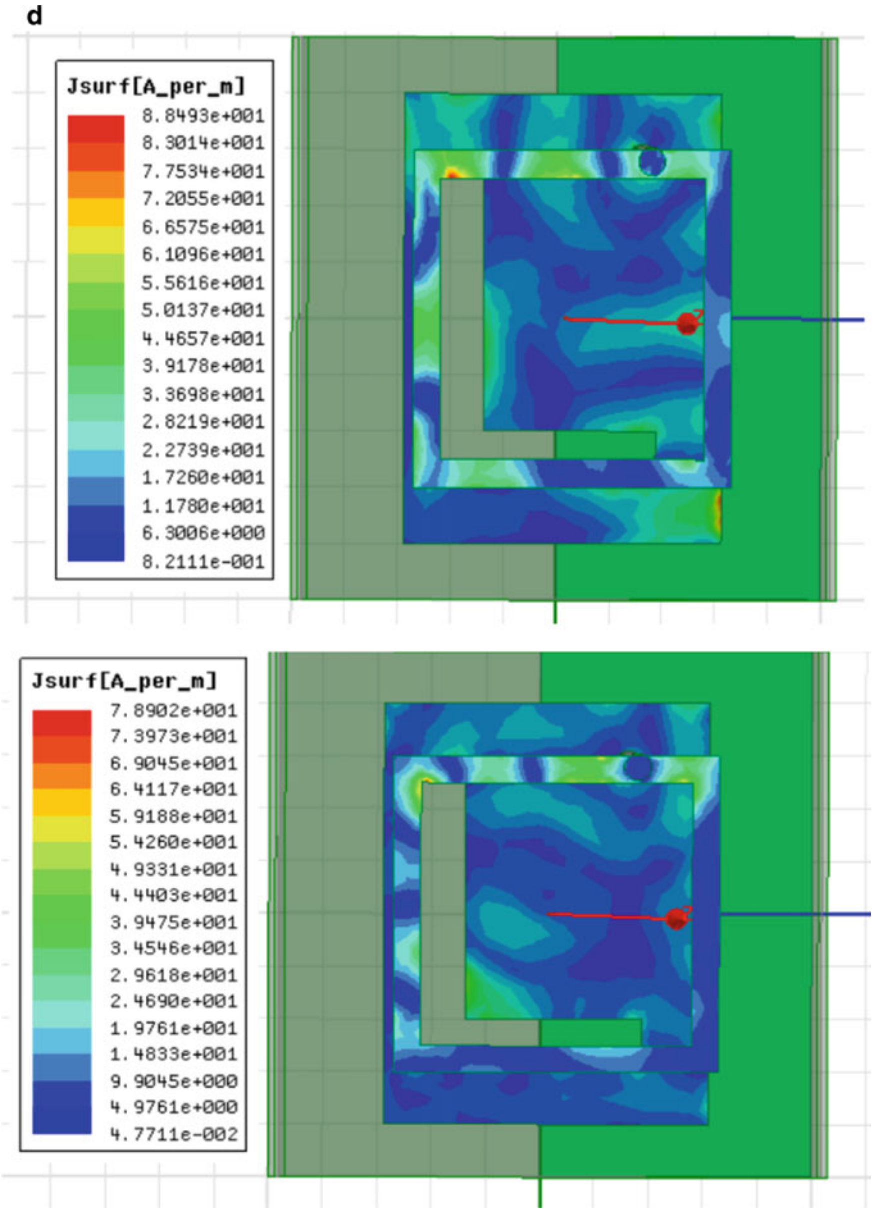

Fig. 2d Current distribution at 28.9 GHz and at 22.9 GHz

e

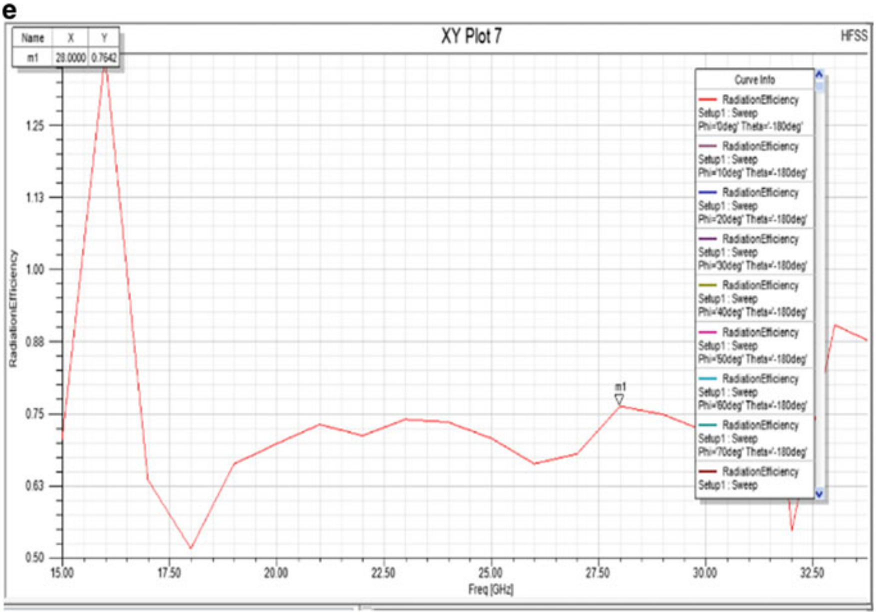

Fig. 2e Simulated radiation efficiency by considering a radiation around the patch antenna

f

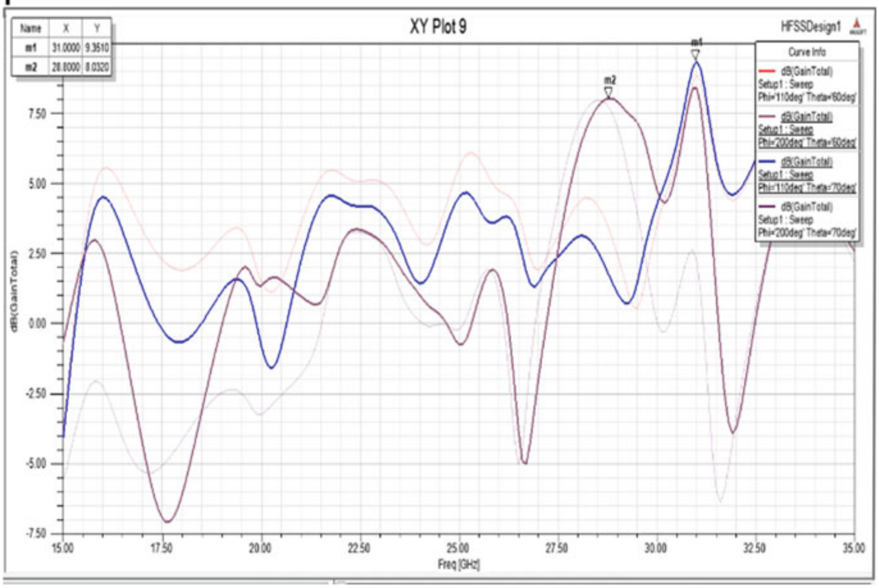

Fig. 2f Simulated result of gain

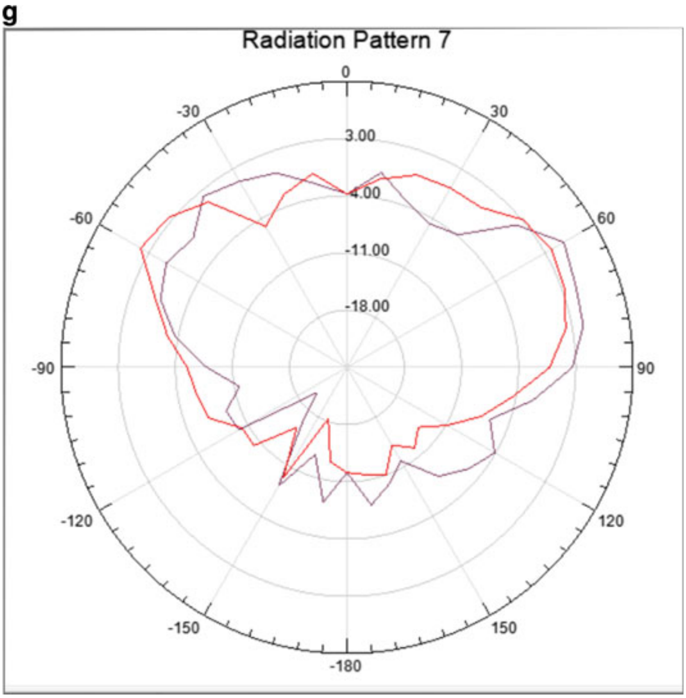

Fig. 2g Simulated radiation pattern for *E*-plane and *H*-plane

Table 1 Advancements in parameters

Antenna/parameters	Reference [2]	Proposed
Volume	20 * 20 * 4.8 mm^3	20 * 20 * 4 mm^3
Bandwidth	8.5 GHz (11.97–20.54 GHz)	16.89 GHz (16.89–33.8 GHz)
Gain	8.5 dB	9.35 dB
Radiation efficiency	88.5%	76%

These results are obtained by simulating proposed antenna in HFSS EM simulator

References

1. Kraus JD, Marhefka RJ, Khan AS, Antenna and wave propagation, 4th edn, pp 500–519
2. Mishra B, Singh V, Singh RK, Singh N, Singh R, A compact UWB patch antenna with defected ground for Ku/K band application. https://doi.org/10.1002/mop.30911
3. Bhadouria AS, Kumar M (2014) Wide Ku-band microstrip patch antenna using defected patch and ground. In: International conference on advanced engineering technology research (ICAETR—2014), IEEE, pp 1–5
4. Matin MA, Sharif BS, Tsimenidis CC (2011) Broadband stacked microstrip antennas with different radiating patch. Wirel Pers Commun 56:637–648

5. Patel AK, Jaiswal K, Pandey AK, Yadav S, Srivastava K, Singh R (2019) A compact inverted V-shaped slotted triple and wideband patch antenna for Ku, K, and Ka band applications. In: RTC2E-LNEE-524, pp 59–67
6. Khandelwal MK, Kanaujia BK, Dwari S, Kumar S, Gautam AK (2014) Bandwidth enhancement and cross-polarization suppression in ultra wideband microstrip antenna with defected ground plane. Microw Opt Technol Lett 56:2141–2146
7. Tan B-K, Withington S, Yassin G (2016) A compact microstrip-fed planar dual-dipole antenna for broadband applications. IEEE Antennas Wirel Propag Lett 15:593–596
8. Prasad PC, Chattoraj N (2013) Design of compact Ku band microstrip antenna for satellite communication. In: International conference on communicational signal process IEEE, pp 196–200
9. Khandelwal MK, Kanaujia BK, Dwari S, Kumar S (2013) Design and analysis of microstrip DGS patch antenna with enhanced bandwidth for Ku Band applications. In: International conference microwave photonics, IEEE, pp 1–4