Planar Antenna Array on LTCC and Rogers substrates for 5G applications

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Abstract— The next generation of wireless communications is the horizon, and the telecoms world is waiting to see exactly at which frequencies 5G will be implemented. Despite some unknowns and technological challenges, it is increasingly becoming clear that the millimeter-wave will be a key enabler for 5G by allocating more bandwidth to deliver faster, higher-quality video, and multimedia content and services. The principal advantage of use of millimeter wave bands is a large amounts of contiguous spectrum can be used, which allows the delivery of high data rates, but the technology is not so mature as in microwave frequencies. This paper presents array antennas using different materials: low-temperature cofired ceramics (LTCC) and Rogers substrates of a single radiating element, 1x1 and 2x2 array. The 2x2 element array antenna achieves a -10 dB bandwidth from 58 to 62 GHz with a peak gain of 12.2 dBi at 60 GHz.

Keywords— aperture-coupled patch antenna, LTCC ,Multi-gigabit communication; 60GHz band; 5G application.

I. INTRODUCTION

Nowadays, consumer device bandwidth requirements are increasing at rapid rates. Historical bands below 3 GHz become crowded, which pushes the development of 5G. At millimeter-wave bands, atmospheric propagation effects can be ignored within around 1 km and antenna size is small enough to be used both in user terminal equipment and base stations [1]. The large 7-9 GHz of unlicensed spectrum band at 60 GHz attracts us with multi-gigabit per second data rates [2]. However, the signal propagation path loss and high packaging integration loss are normally higher than 20 dB [3], which challenges the design of high-gain antennas.

Low-temperature cofired ceramic (LTCC) has been regarded as a promising technology for its flexibility in realizing a number of layers and its highly compact vertical integration [4]. Since the conductor layers in LTCC materials are screen-printed, aperture coupled microstrip slot antennas [5] are a good choice to reduce back radiation, which is an inconvenience in mobile communication. At 60 GHz band, microstrip slot antenna is very small and lightweight.

In this paper, we designed some prototypes on Rogers substrates to compare with the results of LTCC at 60 GHz for 5G application. Six of them with 1x1, 1x2 and 2x2 patches are realized on LTCC. Obtained bandwidths are up to 8% and gains up to 12.2 dBi. Another six are fabricated on substrate, achieving a wide bandwidth of up to 5.2%, with a superior gain of 11 dBi.

II. ANTENNA DESIGN

A. Single Patch Antenna

Fig.1(a) presents the structure of the proposed aperture-coupled patch antenna using LTCC. The top substrate is a 0.336 mm-thick layer of DuPont 9V7k, the bottom substrate is a 0.112 mm-thick layer of the same material. The relative permittivity ϵ_r of

multilayer LTCC substrate is 7.1. Fig.1(b) presents the proposed aperture-coupled patch antenna on Rogers substrates. The top substrate is a 0.127 mm-Rogers 5880, whose relative permittivity ϵ_r is 2.2, followed by a 0.050 mm-thick Rogers 2929, whose relative permittivity ϵ_r is 2.94. The stacked layers below the Rogers 2929 are respectively a 0.018 mm-thick groundplane with an aperture of 0.4 mm x 0.65 mm and a 0.254 mm-thick Rogers 6010, whose relative permittivity(ϵ_r) is 10.2.

Fig.1. (a) Stack-up of Aperture-coupled patch using LTCC.

Fig.1. (b) Stack-up of Aperture-coupled patch using Rogers substrate.

B. Multi-Element Antenna Array

To achieve greater directivity and gain, 1x2 and 2x2 array antennas of the previous basic design are proposed. The sizes of each element remain the same. The quarter-wave transformer strip line is used to maintain a 50 Ω impedance.

However, the discontinuity of the power divider increases the back radiation. To reduce back lobe of radiation pattern, Fig.2 presents the structure of 1x2 array antenna. This junction angle was optimized to distribute the equal power to each radiating element. To reduce the mutual coupling between radiating elements, the optimized value of the inter-element spacing is chosen to be $0.6\lambda_0$.

(a) Top view.

(b) Bottom view.

Fig.2. Structure of 1x2 array antenna.

Fig.3 presents the structure of 2x2 array antenna. The upper two patches are given 180-degrees phase rotation respect to the pair below instead of using an equal feeding phase approach.

Fig.3. Feeding network of 2x2 array antenna.

Table I presents the optimized dimensions of the proposed array using CST MWS.

Param(mm)	LTCC	Rogers	Param(mm)	LTCC	Rogers
W_line	0.12	0.19	L_tf4	0.36	0.56
L1	0.89	1.25	Aperture	0.4x0.65	0.4x0.65
L2	2.06	2.15	L_patch	0.64	1.34
W_tf4	0.33	0.36	R_patch	1.33	0.79

TABLE I. OPTIMIZED ANTENNA DIMENSIONS.

III. COMPARISON BETWEEN LTCC AND ROGERS

A. Gain

Table II presents a summary of the gain results that have been obtained using Rogers substrates and LTCC approaches. The 2x2 array antenna with circular patches using LTCC achieves the highest gain of 12.2 dB at 60 GHz.

Gain (dB)		Circular			Square		
		Ix1	Ix2	2x2	Ix1	Ix2	2x2
LTCC	f=59 GHz	6.22	7.68	11.8	5.45	7.92	11.2
	f=60 GHz	7.39	8.69	12.2	5.41	7.88	11.5
	f=61 GHz	8.19	9.43	12.5	5.36	7.82	11.6
Rogers	f=59 GHz	6.56	7.69	11	6.55	7.8	10.8
	f=60 GHz	6.54	7.36	11.1	6.49	7.6	10.8
	f=61 GHz	6.43	6.89	11	6.34	7.19	10.6

TABLE II. GAIN OF ROGERS SUBSTRATES AND LTCC.

B. Beamwidth

Table III presents a summary of the beamwidth results that have been obtained using Rogers substrates and LTCC approaches at $\varphi=0^\circ$ and $\varphi=90^\circ$. The 2x2 element array using LTCC achieves narrow beamwidth.

Beamwidth($^\circ$)		Circular			Square		
		Ix1	Ix2	2x2	Ix1	Ix2	2x2
LTCC	$\varphi=0^\circ$	65.4	36.8	37.1	84.7	39	34.1
	$\varphi=90^\circ$	63.0	59.6	37.3	109.4	105.7	42.3
Rogers	$\varphi=0^\circ$	81.2	48.4	45.8	81.0	48.7	46.1
	$\varphi=90^\circ$	86.8	81.7	43.8	89.4	80.7	43.5

TABLE III. COMPARISON BEAMWIDTH AT 60 GHZ.

C. S-parameter

Fig.4 presents the S_{11} curves of 2x2 antenna arrays of circular or square patches using Rogers substrates and LTCC.

Fig.4. 2x2 Array Comparison of S_{11} .

D. Radiation Pattern of the best option

Fig.5. presents the radiation pattern of the 2x2 LTCC array antenna with the highest gain.

Fig.5. Radiation Pattern of the 2x2 LTCC array antenna.

IV. CONCLUSION

Planar antenna arrays are presented at 60 GHz with two different materials: LTCC and Rogers substrates. From the results of simulation, we can find that LTCC has a better performance at 60 GHz band in comparison to Rogers substrates in the aspects of S-parameter, bandwidth, losses, crosspolar, gain and directivity. The 2x2 element array with circular patch using LTCC can achieve a maximum gain of 12.2 dB at 60 GHz. Prototype measurement results will be presented in ISAP 2017.

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VI. REFERENCES

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