DESIGN, FABRICATION AND CHARACTERIZATION OF RF FRONT-END 5G WIRELESS SYSTEM

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by

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LIST OF ABBREVIATIONS

5G	Fifth-generation
AC	Alternating current
ADS	Advanced Design System
AM	Amplitude modulation
BPF	Bandpass filter
CCTO	$CaCu_3Ti_4O_{12}$
CDMA	Code-division multiple access
CST	Computer Simulation Technology
dB	Decibel
dBm	Power ratio in decibel
DC	Direct current
DRF	Dielectric Resonator Filter
DRs	Dielectric resonators
ε_r	Dielectric constant
fc	Cut-off frequency
FCC	Federal Communications Commission
f_H	Higher cut-off frequency
f_L	Lower cut-off frequency

GSM	Global System for Mobile Communication
H/D	Ratio of the thickness over the diameter
HBT	Heterojunction bipolar transistor
HD	High Definition
I/Q	Inphase / Quadrature
IF	Intermediate frequency
IP	Internet Protocol
IPV6	Internet Protocol version 6
LAS-CDMA	Large area synchronized code-division multiple access
LMDS	Local Multipoint Distribution Service
LNA	Low noise amplifier
LO	Local Oscillator
MAC	Medium access control
MC-CDMA	Multi-carrier code-division multiple access
MMIC	Monolithic Microwave Integrated Circuit
NF	Noise figure
NPRM	Notice of Proposed Rule Making
OFDMA	Orthogonal frequency-division multiple access
PA	Power amplifier

PCB	Printed circuit board
PHY	Physical layer
Q	Quality factor
RF	Radio Frequency
SMT	Surface mount technology
SNR	Signal noise ratio
TEM	Transverse electromagnetic wave
UHF	Ultra-high frequency
VCO	Voltage controlled oscillator
V_{cont}	Control voltage
WiGig	Wireless Gigabit Alliance
Z_{0e}	Even-mode
Z_{0o}	Odd-mode
ZST	$(Zr_{0.8}, Sn_{0.2})\ TiO_4$

REKA BENTUK, FABRIKASI DAN PENCIRIAN RF HUJUNG-DEPAN SISTEM TANPA WAYAR 5G

ABSTRAK

Pertumbuhan data selular yang tidak dijangka telah memberi cabaran terhadap penyedia perkhidmatan rangkaian mudah alih bagi menghadapi kekurangan saiz jalur lebar tanpa wayar yang telah diselaraskan di seluruh dunia. Kesukaran yang disebabkan oleh kekurangan jalur lebar bagi perkhidmatan mudah alih tanpa wayar telah menarik minat terhadap penerokaan spektrum gelombang frekuensi milimeter yang tidak digunakan untuk teknologi mudah alih jalur lebar pada masa hadapan. Sistem pemancarterima RF tanpa wayar yang beroperasi pada frekuensi gelombang milimeter (mm-Wave) 28 GHz direka dan dibangunkan untuk aplikasi rangkaian selular 5G. Satu siri sistem RF hujung-depan pemancarterima terdiri daripada pemancar RF dan penerima RF. Sistem RF hujung-depan ini menyediakan lebar jalur penghantaran yang luas iaitu 1000 MHz. Prototaip pemancarterima RF dibangunkan dengan menggunakan komponen sedia siap dari Avago Technologies dan Hittite Microwave kecuali penapis laluan jalur 1 GHz dan 28 GHz. Reka bentuk seni bina superheterodin bagi pemancar dan superheterodin bagi penerima digunakan untuk membangunkan reka bentuk sistem RF hujung-depan ini. Terdapat dua jenis penapis laluan jalur yang direka dalam projek ini; elemen tergumpal untuk frekuensi rendah pada 1 GHz dan Penapis Resonator Dielektrik (DRF) untuk frekuensi mm-Wave pada 28 GHz. Penapis laluan jalur jenis elemen tergumpal direka pada frekuensi tengah 1 GHz dengan lebar jalur penghantaran 1000 MHz. Penapis laluan jalur bagi 28 GHz direka dengan menggunakan kombinasi penapis mikrostrip gabungan selari dan penyalun dielektrik (DRs) yang diperbuat daripada CaCu3Ti4O12 (CCTO).

Penggunaan dielektrik resonator bagi reka bentuk litar gelombang mikro secara langsung dapat membantu meningkatkan prestasi litar dari segi faktor-Q dan saiz jalur lebar. Penapis laluan jalur dielektrik resonator menghasilkan lebar jalur penghantaran 1000 MHz yang beroperasi pada frekuensi pertengahan 28 GHz. Simulasi reka bentuk keseluruhan pemancarterima RF dijalankan dengan menggunakan Advanced System Design (ADS). Computer Simulation Technology (CST) digunakan untuk mereka bentuk penapis laluan jalur 28 GHz dengan menggunakan dielektrik resonator. Pengesahan reka bentuk dilaksanakan melalui pengujian perkakasan terhadap pemancar RF dan RF penerima. Sistem pemancar RF berfungsi untuk menukar-naik isyarat input IF pada 1 GHz kepada isyarat output RF pada 28 GHz, sementara penerima RF digunakan untuk menukar-turun isyarat input RF pada 28 GHz kepada isyarat output IF pada 1 GHz. Berdasarkan keputusan eksperimen untuk pemancarterima RF 28 GHz, jumlah kuasa output yang tertinggi dan terendah bagi isyarat IF dicatatkan pada -13.12 dBm melalui attenuator 10 dB dan –45.77 dBm melalui attenuator 50 dB apabila kuasa bagi input isyarat IF ditetapkan pada -20 dBm. Peratusan kelinearan bagi output isyarat IF diperoleh pada sekitar 80% apabila isyarat IF pada 1GHz ditetapkan pad -20 dBm kuasa input. Keseluruhan projek RF hujung-depan 28 GHz untuk aplikasi rangkaian selular berjaya direka bentuk dan dibangunkan.

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ABSTRACT

The unexpected increase of cellular data growth has created absolute challenges for the mobile network service providers in order to counter with a worldwide wireless bandwidth shortage. The difficulty of mobile wireless bandwidth size shortage has attracted the interest towards the exploration of the underutilized millimetre-wave frequency spectrum for the future broadband mobile technologies. A wireless RF transceiver system operating at the millimetre wave (mm-Wave) frequency of 28 GHz for the 5G cellular network application is designed and fabricated. A series of RF front-end transceiver system consists of the RF transmitter and RF receiver. This RF front-end system provides a wide transmission bandwidth of 1000 MHz. The RF transceiver prototype is built using off-the-shelf components from the Avago Technologies and Hittite Microwave except for the 1 GHz and 28 GHz bandpass filters. The superheterodyne transmitter and superheterodyne receiver architectural designs are used to develop this RF front-end system design. There are two types of bandpass filter are designed in this project; lumped elements for low frequency at 1 GHz and Dielectric Resonator Filter (DRF) for mm-Wave frequency at 28 GHz. The lumped elements bandpass filter is designed at the centre frequency of 1 GHz with the transmission bandwidth of 1000 MHz. The 28 GHz bandpass filter is designed by using a combination of microstrip parallel-coupled filter and the dielectric resonators (DRs) made of $CaCu_3Ti_4O_{12}$ (CCTO). The use of a dielectric resonator for the microwave circuit design directly can help to improve the performance of the circuit in terms of Q-factor and bandwidth size. The dielectric resonator bandpass filter produces a transmission bandwidth of 1000 MHz operating at the centre frequency of 28 GHz. The overall simulation design of the RF transceiver is carried out using Advanced Design System (ADS). Computer Simulation Technology (CST) is used to design the 28 GHz bandpass filter using dielectric resonators. The verification of design is accomplished through the RF transmitter and RF receiver hardware testing. The RF transmitter system works to up-convert an input IF signal at 1 GHz to an output RF signal at 28 GHz, while the RF receiver used to down-convert an input RF signal at 28 GHz to an output IF signal at 1 GHz. Based on the experimental results for the 28 GHz RF transceiver, the highest and lowest amount of IF signal output power are recorded at -13.12 dBm via 10 dB attenuator and -45.77 dBm via 50 dB attenuator when the IF signal input power is set at -20 dBm. The linearity of the IF signal output power is obtained around 80% when the 1 GHz IF signal is set at -20 dBm input power. The overall project of the 28 GHz RF front-end for the cellular network application is successfully designed and developed.