

**SYNTHESIZE AND CHARACTERIZATION OF  
Al<sub>2</sub>O<sub>3</sub>-, BaTiO<sub>3</sub>-, TiO<sub>2</sub>-, CuO-CCTO COMPOSITES  
FOR WIDEBAND DIELECTRIC RESONATOR  
APPLICATION**

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**SYNTHESIZE AND CHARACTERIZATION OF  $\text{Al}_2\text{O}_3$ -,  $\text{BaTiO}_3$ -,  $\text{TiO}_2$ -,  
 $\text{CuO}$ - $\text{CCTO}$  COMPOSITES FOR WIDEBAND DIELECTRIC RESONATOR  
APPLICATION**

**by**

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**Thesis submitted in fulfilment of the  
requirements for the degree of  
Doctor of Philosophy**

**Mac 2018**

## **DECLARATION**

I hereby declare that I am the sole author of this dissertation. This is a true copy of the dissertation, including any required final revisions, as accepted by my examiners. It has not previously submitted for the basis of the award of any degree or diploma or other similar title of this for any other diploma/examining body or university. I understand that my dissertation maybe made electronically available to the public.

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## LIST OF ABBREVIATION

BW%	Percentage of bandwidth
DRA	Dielectric resonance antenna
EDX	Energy Dispersive X-ray
RL	Return loss
FESEM	Field Emission Scanning Electron Microscopy
XRD	X-ray Diffraction

## LIST OF SYMBOLS

%	Percentage
°	Degree
°C	Degree Celsius
°C/min	Degree Celsius per minutes
MPa	Megapascal
$\lambda$	Wavelength
$\epsilon_r$	Dielectric constant
$\tan \delta$	Tangent loss

**SINTESIS DAN PENCIRIAN KOMPOSIT  $\text{Al}_2\text{O}_3$ -,  $\text{BaTiO}_3$ -,  $\text{TiO}_2$ -,  
 $\text{CuO}$ -CCTO UNTUK KEGUNAAN PENYALUN DIELEKTRIK JALUR  
LEBAR**

**ABSTRAK**

Antena logam telah digunakan secara meluas dalam sistem komunikasi tanpa wayar sejak beberapa tahun yang lalu. Secara umum saiz antena yang digunakan adalah besar disamping kehilangan haba ( $\tan \delta$ ) yang tinggi dan jalur lebar yang kecil. Kelemahan ini boleh diselesaikan dengan menggunakan bahan seramik dengan pemalar dielektrik ( $\epsilon_r$ ) yang tinggi dan kehilangan haba yang rendah seperti  $\text{CaCu}_3\text{Ti}_4\text{O}_{12}$  (CCTO) yang juga dikenali sebagai antena penyalun elektrik (DRA). Pada frekuensi 8 GHz, didapati bahawa  $\epsilon_r$  CCTO ialah 62.76 dan  $\tan \delta$  adalah 0.1458. Ia menghasilkan isyarat antara 8.56-9.12 GHz dengan 6.60% jalur lebar. Tetapi  $\tan \delta$  bagi CCTO adalah tinggi iaitu lebih daripada 0.1 dan liputan jalur lebar kurang daripada 10% dimana ia tidak mampu meliputi bahagian yang lebih luas dalam sistem komunikasi jalur X (8 GHz hingga 12 GHz). Oleh itu, untuk meningkatkan potensi CCTO sebagai DRA yang lebih baik, bahan oksida yang lain perlu ditambah. Dalam kajian ini,  $\text{Al}_2\text{O}_3$ ,  $\text{BaTiO}_3$ ,  $\text{TiO}_2$  and  $\text{CuO}$  telah ditambah daripada 20, 40, 50, 60, dan 80 wt% kepada CCTO. Didapati bahawa  $\epsilon_r$  bagi penambahan  $\text{Al}_2\text{O}_3$  kepada CCTO ialah 37.33 dan  $\tan \delta$  dalam siri komposit ini ditambah baik ke nilai yang lebih rendah iaitu 0.0520. Komposit ini menghasilkan isyarat antara 8.67-9.26 GHz dengan lebar jalur 5.61% (penambahan 20 wt%  $\text{Al}_2\text{O}_3$ ). Penambahan  $\text{BaTiO}_3$  telah meningkatkan  $\epsilon_r$  kepada 85.23 dan  $\tan \delta$  dalam siri ini antara 0.0627-0.0258. Hasil kajian menunjukkan komposit ini menghasilkan isyarat antara 9.33-10.21 GHz dengan 8.91% jalur lebar.

Penambahan 50 wt%  $\text{TiO}_2$  menunjukkan  $\epsilon_r$  berubah kepada 56.47 dan  $\tan \delta$  dalam siri tersebut antara 0.0165-0.1108. Apabila di uji sebagai antenna ia menyalun antara 10.03-11.36 GHz dengan 12.48% jalur lebar.  $\epsilon_r$  yang tinggi iaitu 67.52 diperolehi daripada dengan penambahan 50wt% CuO dan  $\tan \delta$  antara 0.0203-0.0878 serta menghasilkan isyarat pada julat 9.12-11.29 GHz dengan 21.26% jalur lebar. Semua keputusan ini menunjukkan bahawa semua sampel yang diuji boleh digunakan sebagai antenna tetapi siri 50CCTO/50CuO menunjukkan prestasi yang terbaik berbanding dengan siri lain. Atas sebab itu, siri komposit ini seterusnya dioptimumkan dan didapati bahawa siri komposit (50CCTO/50CuO) ini menghasilkan  $\epsilon_r$  yang tinggi iaitu 67.52 dan  $\tan \delta$  yang rendah (0.0141). Siri komposit ini boleh meliputi julat frekuensi yang lebih luas dalam jalur X dan ia sesuai untuk dijadikan DRA dalam saiz yang lebih kecil dengan prestasi yang lebih baik.

**SYNTHESIZE AND CHARACTERIZATION OF Al<sub>2</sub>O<sub>3</sub>-, BaTiO<sub>3</sub>-, TiO<sub>2</sub>-,  
CuO-CCTO COMPOSITES FOR WIDEBAND DIELECTRIC RESONATOR  
APPLICATION**

**ABSTRACT**

Metallic antennas have been widely used in wireless communication system. In general this antenna is big in size with high tangent loss ( $\tan \delta$ ) and the bandwidth is narrow with low efficiency. These shortcomings can be solved by using ceramic materials with high dielectric constant ( $\epsilon_r$ ) and low  $\tan \delta$  such as CaCu<sub>3</sub>Ti<sub>4</sub>O<sub>12</sub> (CCTO), known as dielectric resonator antenna (DRA). At 8 GHz,  $\epsilon_r$  is 62.76 and  $\tan \delta$  is 0.1458 and resonated between 8.56 to 9.12 GHz with 6.6% bandwidth. However, its  $\tan \delta$  is still considered as on the higher side ( $>0.1$ ) and bandwidth coverage is less than 10% which is not able to cover a wider portion of the X band (8 GHz to 12 GHz) communication system. Therefore, to enhance the properties of DRA, CCTO properties can be modified through the addition with other oxides. In this research, Al<sub>2</sub>O<sub>3</sub>, BaTiO<sub>3</sub>, TiO<sub>2</sub> and CuO, respectively, was added from 20, 40, 50, 60, and 80 wt% into CCTO. It was found that addition of Al<sub>2</sub>O<sub>3</sub> has reduced  $\epsilon_r$  to 37.33 but has improved  $\tan \delta$  value to the lowest value of 0.0520. This antenna resonated between 8.67 to 9.26 GHz with 5.61% bandwidth (addition 20 wt% Al<sub>2</sub>O<sub>3</sub>). The addition of BaTiO<sub>3</sub> has increased  $\epsilon_r$  to 85.23 with addition 80 wt% and  $\tan \delta$  in these series between 0.0627 – 0.0258. The result shows these composites resonated between 9.33 to 10.21 GHz with 8.91% bandwidth. The addition of 50 wt% of TiO<sub>2</sub> shows  $\epsilon_r$  of 56.47 and  $\tan \delta$  of these composites between 0.0165-0.1108, resonated from 10.03 to 11.36 GHz with 12.48% bandwidth. The highest  $\epsilon_r$  (67.52) was obtained from 50 wt%