

Superconductivity - Part 17: Electronic characteristic measurements - Local critical current density and its distribution in large-area superconducting films

## EESTI STANDARDI EESSÕNA

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English Version

**Superconductivity - Part 17: Electronic characteristic  
measurements - Local critical current density and its distribution  
in large-area superconducting films  
(IEC 61788-17:2021)**

Supraconductivité - Partie 17: Mesures de caractéristiques  
électroniques - Densité de courant critique local et sa  
distribution dans les films supraconducteurs de grande  
surface  
(IEC 61788-17:2021)

Supraleitfähigkeit - Teil 17: Messungen der elektronischen  
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The text of document 90/462/FDIS, future edition 2 of IEC 61788-17, prepared by IEC/TC 90 "Superconductivity" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61788-17:2021.

The following dates are fixed:

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(normative)

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<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-815	-	International Electrotechnical Vocabulary - Part 815: Superconductivity	-	-

# INTERNATIONAL STANDARD



**Superconductivity –  
Part 17: Electronic characteristic measurements – Local critical current density  
and its distribution in large-area superconducting films**



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# INTERNATIONAL STANDARD



## Superconductivity –

### Part 17: Electronic characteristic measurements – Local critical current density and its distribution in large-area superconducting films

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**SUPERCONDUCTIVITY –****Part 17: Electronic characteristic measurements –  
Local critical current density and its distribution  
in large-area superconducting films****FOREWORD**

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This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following a significant technical change with respect to the previous edition:

- a) A simple method to calculate theoretical coil coefficient  $k$  is described in 6.2.1.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
90/462/FDIS	90/464/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

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## INTRODUCTION

Over thirty years after their discovery in 1986, high-temperature superconductors are now finding their way into products and technologies that will revolutionize information transmission, transportation, and energy. Among them, high-temperature superconducting (HTS) microwave filters, which exploit the extremely low surface resistance of superconductors, have already been commercialized. They have two major advantages over conventional non-superconducting filters, namely: low insertion loss (low noise characteristics) and high frequency selectivity (sharp cut) [1]<sup>1</sup>. These advantages enable a reduced number of base stations, improved speech quality, more efficient use of frequency bandwidths, and reduced unnecessary radio wave noise.

Large-area superconducting thin films have been developed for use in microwave devices [2]. They are also considered for use in emerging superconducting power devices, such as resistive-type superconducting fault-current limiters (SFCLs) [3] [4] [5], superconducting fault detectors used for superconductor-triggered fault current limiters [6] [7] and persistent-current switches used for persistent-current HTS magnets [8] [9]. The critical current density  $J_c$  is one of the key parameters that describe the quality of large-area HTS films. Nondestructive, AC inductive methods are widely used to measure  $J_c$  and its distribution for large-area HTS films [10] [11] [12] [13], among which the method utilizing third-harmonic voltages  $U_3 \cos(3\omega t + \theta)$  is the most popular [10] [11], where  $\omega$ ,  $t$  and  $\theta$  denote the angular frequency, time, and initial phase, respectively. However, these conventional methods are not accurate because they have not considered the electric-field  $E$  criterion of the  $J_c$  measurement [14] [15] and sometimes use an inappropriate criterion to determine the threshold current  $I_{th}$  from which  $J_c$  is calculated [16]. A conventional method can obtain  $J_c$  values that differ from the accurate values by 10 % to 20 % [15]. It is thus important to establish standard test methods to precisely measure the local critical current density and its distribution, to which all involved in the HTS filter industry can refer for quality control of the HTS films. Background knowledge on the inductive  $J_c$  measurements of HTS thin films is summarized in Annex A.

In these inductive methods, AC magnetic fields are generated with AC currents  $I_0 \cos \omega t$  in a small coil mounted just above the film, and  $J_c$  is calculated from the threshold coil current  $I_{th}$ , at which full penetration of the magnetic field to the film is achieved [17]. For the inductive method using third-harmonic voltages  $U_3$ ,  $U_3$  is measured as a function of  $I_0$ , and the  $I_{th}$  is determined as the coil current  $I_0$  at which  $U_3$  starts to emerge. The induced electric fields  $E$  in the superconducting film at  $I_0 = I_{th}$ , which are proportional to the frequency  $f$  of the AC current, can be estimated by a simple Bean model [14]. A standard method has been proposed to precisely measure  $J_c$  with an electric-field criterion by detecting  $U_3$  and obtaining the  $n$ -value (index of the power-law  $E$ - $J$  characteristics) by measuring  $I_{th}$  precisely at various frequencies [14] [15] [18] [19]. This method not only obtains precise  $J_c$  values, but also facilitates the detection of degraded parts in inhomogeneous specimens, because the decline of  $n$ -value is more noticeable than the decrease of  $J_c$  in such parts [15]. It is noted that this standard method is excellent for assessing homogeneity in large-area HTS films, although the relevant parameter for designing microwave devices is not  $J_c$ , but the surface resistance. For application of large-area superconducting thin films to SFCLs, knowledge on  $J_c$  distribution is vital, because  $J_c$  distribution significantly affects quench distribution in SFCLs during faults.

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