ISO/IEC JTC1/SC17 2010-01-25

Cards and personal identification

ISO/IEC JTC1/SC17 N 3858 **WG8 N 1652**

DOCUMENT TYPE: Notification of Ballot

TITLE: Notification of ballot - ISO/IEC 10373-6/Amd 9:2001 - Identification cards - Test methods - Part 6: Proximity cards - AMENDMENT 9: Test methods for electromagnetic disturbances.

BACKWARD POINTER:

SOURCE: SECRETARIAT ISO/IEC JTC1/SC17

STATUS: This ballot has been posted to the ISO Electronic balloting application and is available under the Balloting Portal, Committee Internal Balloting.

ACTION ID: Vote

WORK ITEM:

DUE DATE: 2010-04-26

DISTRIBUTION: P and L-Members of ISO/IEC JTC1/SC17
JTC1 Secretariat
ISO/IEC ITTF

MEDIUM: SERVER

NO. OF PAGES: 19

Secretariat ISO/IEC JTC1/SC17, UK Payments, Mercury House, Triton Court, 14 Finsbury Square, London EC2A 1LQ, England;
Telephone +44 (0)20 7711 6255; Fax: +44 (0)20 7711 6299; e-mail: chris.starr@ukpayments.org.uk

WG8 N 1632 R3

ISO/IEC JTC 1/SC 17 N xxxx

Date: 2010-01-21

ISO/IEC 10373-6:2001/PDAM 9

ISO/IEC JTC 1/SC 17/WG 8

Secretariat: DIN(florian.peters@bdr.de)

Identification cards — Test methods — Part 6: Proximity cards

AMENDMENT 9: Test methods for electromagnetic disturbances

Cartes d'identification — Méthodes d'essai — Partie 6: Cartes de proximité

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AMENDMENT 9: Méthodes d'essai pour les perturbations électromagnétiques

Document type: International Standard
Document subtype: Amendment
Document stage: (30) Committee
Document language: E

C:\Users\radiomondiale\Documents\a_bdr\a_wg8\V A L E N C E 2009\AMD9\WD10373-6_AMD9_1632R2.doc STD Version 2.1c2

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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Amendment 9 to ISO/IEC 10373-6:2009 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Cards and personal identification*.

Introduction

The electromagnetic disturbance (EMD) level refers to the EMD parasitically generated by the PICC through the activities of the digital circuits. A too-high EMD level can disrupt the communication between the PCD and the PICC because it can be incorrectly interpreted by the PCD as a valid PICC to PCD communication. Therefore, the EMD emitted by the PICC immediately before its response, shall not exceed a maximum value.

The EMD is determined like load modulation with a time domain measurement.

Identification cards — Test methods — Part 6: Proximity cards

AMENDMENT 9: Test methods for electromagnetic disturbances

Page 3, clause 3.2

Add the following symbols to the list of abbreviations and symbols

EMD Electromagnetic disturbance as defined in ISO/IEC 14443-2

$t_{E,PICC}$ Low EMD time, PICC

$t_{E,PCD}$ Low EMD time, PCD

$V_{E,PICC}$ EMD limit, PICC

$V_{E,PCD}$ EMD limit, PCD

V_{LOAD} DC voltage measured at CON3 of the Reference PICC

V_{EMD} Electromagnetic disturbance amplitude

t_{START} Start of PICC transmission

ProjectEditor: All symbols except t_{START} are also already present in parts and amendments of ISO/IEC 14443, however, we intent to keep it until FDIS for better understanding of this new Amd.

ProjectEditor:

All references to pages and clause numbers are according to ISO/IEC FDIS 10373-6:2010.

Page 7, clause 5.1.1

Insert the following new sub clause 5.2 after sub clause 5.1.1 and renumber all subsequent subclauses:

5.2 EMD Test Setup

5.2.1 General description

The PICC EMD test methods include a power versus time measurement. The test equipment used for this measurement shall be able to carry out a power versus time measurement with fixed frequency, fixed bandwidth, high dynamic range, low measurement uncertainty and high time resolution.

The EMD test setup contains a signal generator with low phase noise, which is used to synthesize both an EMD test pattern and PCD test commands sent to the PICC under test.

NOTE The PICC EMD tests may be performed using the RF output signal of a commercial PCD. The PCD EMD test may use a PICC emulator to generate the EMD test pattern.

5.2.2 Computation of power vs. time

The test setup shall have the capability of calculating power as a function of time. Each value of power shall be computed by a Fourier transformation of a captured field signal. This captured signal shall be windowed by a Bartlett window of exact two subcarrier cycles before transformation. Shifting the Bartlett window by steps of 1/*fc* shall be used to produce the desired power vs. time result.

NOTE The resulting 3dB-bandwidth of the above described window is 531 kHz and its noise equivalent bandwidth amounts to 843 kHz.

Fourier transformation shall be done at the frequencies *fc* + *fs* and *fc* − *fs*, using a scaling such that a pure sinusoidal signal results in its peak magnitude. This calculation can be done by the example of implementation given in ANNEX I.

Alternative test setups (e.g. a spectrum analyzer) with at least an equivalent analysis bandwidth may also be used. The alternative device shall pass the noise floor precondition test, as defined in 5.2.3, and there shall be some additional margin on $t_{E,\,PICC}$ requirement and no spikes above the EMD limit.

5.2.3 Noise floor precondition test

In order to ensure a high dynamic range and sufficient sensitivity, a noise floor measurement shall be performed and passed successfully by the EMD test setup.

The aim of this precondition test is to verify that the test apparatus used for EMD level measurement satisfies a minimum noise requirement. The noise floor test is passed if the noise standard deviation is at least three times smaller than the EMD limit $V_{E,\,PICC}$, when measured as described in 5.2.3.1.

The noise standard deviation is determined by calculating the root-mean-square value of the results of the Fourier transformation, as described in 5.2.2.

NOTE This noise floor can be obtained either with a 14-bit digitizer at a sampling rate of 100 million samples per second or with an 8-bit digital oscilloscope at sampling rate of 1 billion samples per second.

5.2.3.1 Test Procedure

Perform the following steps to assess the noise floor at least at H_{min} and H_{max}.

a) Tune the Reference PICC to 13,56 MHz.

b) Adjust the RF power delivered by the signal generator to the test PCD antenna to the required field strength as measured by the calibration coil.

c) Put the Reference PICC in the DUT position of the test PCD assembly and adjust R2 to obtain a V_{LOAD} of 6 V (DC) at CON3. Alternatively jumper J1 may be set to position 'c' and the applied voltage on CON2 is adjusted to obtain a V_{LOAD} of 6 V (DC) at CON2. The RF drive into the test PCD antenna shall be re-adjusted to the required field strength if necessary.

d) Record the sense coils' signal for a time period of at least 250 µs.

e) Compute the noise standard deviations at *fc* + *fs* and *fc* − *fs* using suitable computer software, as e.g. the one given in ANNEX I. Check if these noise standard deviations are three times smaller than $V_{E,PICC}$.

5.2.3.2 Test Report

The test report shall report the noise standard deviations at *fc* + *fs* and *fc* – *fs* together with a statement whether the requirements have been fulfilled.

Page 18, clause 7.1.5

Insert the following new sub clauses 7.1.6 and 7.1.7 after sub clause 7.1.5:

7.1.6 PCD EMD Immunity Test

7.1.6.1 Purpose

The purpose of this test is to determine whether the PCD is insensitive to any load modulation amplitude below $V_{E,PCD.}$

NOTE The low EMD time $t_{E, PCD}$ is a function of FDT/TR0 as defined in Amd.4 of ISO/IEC 14443-3.

7.1.6.2 Test Procedure

a) Tune the Reference PICC to 13.56 MHz as described in 5.4.3 and switch the Jumper J1 to position 'c'.

b) Place the Reference PICC at a particular position in the PCD operating volume.

c) Apply and adjust a DC voltage at CON2 to obtain a V_{LOAD} at connector CON3 of 3 V (DC) or optionally 6 V (DC) when supporting Class 1 at that position.

d) Send the appropriate test pattern "A1" for Type A or "B1" for Type B as shown in Amd.9.1. The test pattern is given in Figure Amd.9.2 and Figure Amd.9.3. The initial V_{LMA} (named V_{EMD}) of the test pattern shall be lower than $V_{E, PCD.}$

e) Immediately after this test pattern, applying no gap, send the appropriate PICC answer to the PCD command with a V_{LMA}, measured as defined in 7.2.1, of a higher level than the minimum value for the applied field strength *H*.

f) Increase the V_{EMD} of the test pattern by adjusting the voltage at CON1 until the PCD does no longer detect the answer correctly. This may be determined by monitoring the next PCD command following the PICC answer, see Figure Amd.9.1.

g) Place the Reference PICC in the DUT position on the Test PCD assembly.

h) Adjust the Test PCD assembly to produce a field strength *H* which gives the same V_{LOAD} at CON3 and note the corresponding field strength by reading the calibration coil voltage.

i) Derive the current value of the Reference PICC's V_{EMD} by applying the power vs. time measurement as described in 5.2.2.

j) Compare this measured V_{EMD} level with $V_{E, PCD}$.

Repeat step a) to j) for various positions within the operating volume.

7.1.6.3 Test report

The test report shall report whether the PCD was insensitive to any load modulation amplitude below $V_{E, PCD}$.

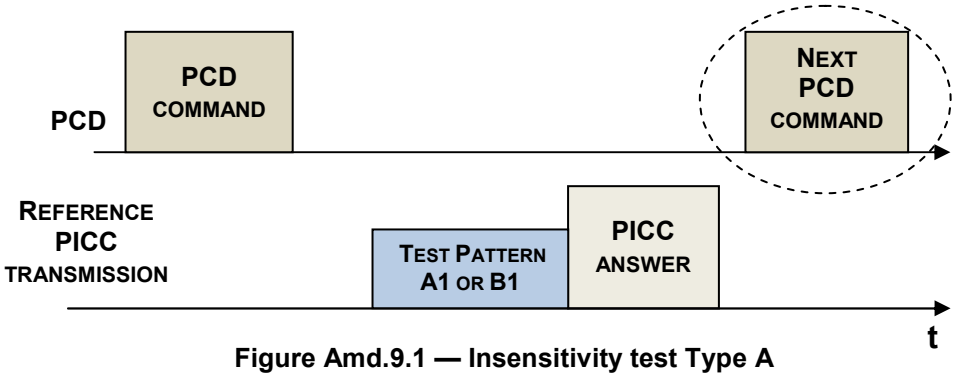

Figure Amd.9.1 — Insensitivity test Type A

Figure Amd.9.2: Pattern "A1" for PCD immunity test (Type A)

Start Bit	Data	Parity	Stop bit	CRC
yes	(01011101)b	yes	yes	yes

Project Editor: Please comment on:

T.b.d. if both may just be replaced by saying "send a valid standard frame with information (01011101)b ?

Figure Amd.9.3: Pattern "B1" for PCD immunity test (Type B)

TR1/SOF	Start Bit	Data	CRC	Stop Bit	EOF
yes	yes	(01011101)b	yes	yes	yes

7.1.7 PCD EMD Recovery Test

7.1.7.1 Purpose

The purpose of this test is to determine whether the PCD is able to recover from a test pattern within the duration of $t_{E,\,PCD}$.

7.1.7.2 Test procedure

a) Tune the Reference PICC to 13.56 MHz as described in 5.4.3.

b) Calibrate the Test PCD assembly to produce the H_{min} operating condition on the calibration coil.

c) Place the Reference PICC into the DUT position on the Test PCD assembly. Switch the jumper J1 to 'b' and adjust R2 to obtain a V_{LOAD} of 6V (DC) measured at CON3. Alternatively, jumper J1 may be set to 'c' and the applied voltage at CON2 is adjusted to obtain a V_{LOAD} of 6V (DC) at CON3. In both cases, the operating field condition shall be verified by monitoring the voltage on the calibration coil. and the voltage adjusted if necessary.

d) Find the appropriate driving voltage at CON1 to produce a V_{LMA}, measured as defined in 7.2.1, higher than the limit for H_{min}, defined in ISO/IEC 14443-2.

e) Place the Reference PICC at a position within the operating volume of the PCD where 6V (DC) is obtained at CON3.

f) Send in sequence, as illustrated in Figure Amd.9.4 using the $t_{E,\,PICC}$ associated with FDT/TR0

— a test pattern, which starts sending the data (01)b in a valid way to the PCD, but interrupts immediately after the second bit sent, as illustrated in Figure Amd.9.5 for Type A and Amd.9.6 for Type B.

— a period with no load modulation for a duration of $t_{E,\,PCD}$,

— the appropriate answer to the PCD command.

g) Check if the PCD behaves in the same way as if there was no test pattern.

h) Repeat step a) to g) 10 times.

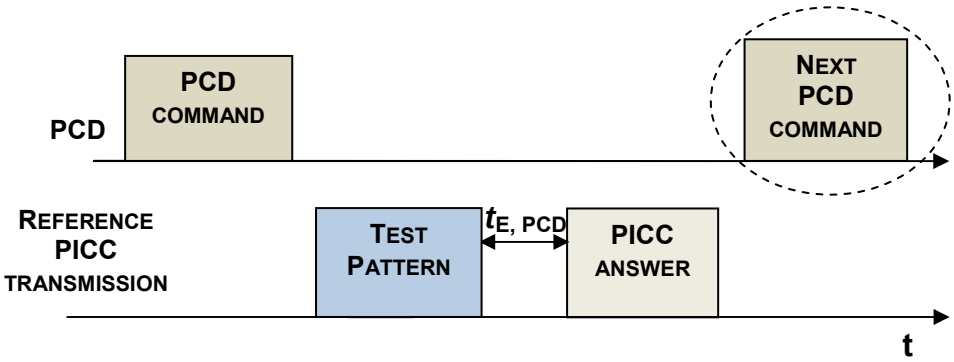

Figure Amd.9.4 — Recovery test sequence

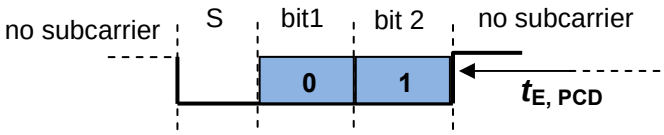

Figure Amd.9.5 — Test pattern for the EMD recovery test (Type A)

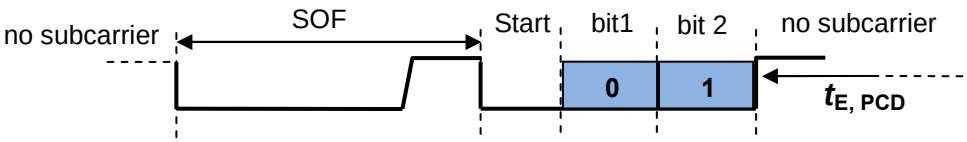

Figure Amd.9.6 — Test pattern for the EMD recovery test (Type B)

7.1.7.3 Test Report

The test report shall report whether the PCD was not disturbed by the test pattern, resp. has recovered from the test pattern during the low EMD time $t_{E,PCD}$.

Page 19, clause 7.2.1

Insert the following new sub clause 7.2.2 after sub clause 7.2.1 and renumber all subsequent subclauses:

7.2.2 PICC EMD level and low EMD time test

7.2.2.1 Purpose

The purpose of this test is to determine whether the PICC does not generate V_{EMD} higher than $V_{E,\ PICC}$ during $t_{E,PICC}$ with exceptions defined in Amd.3 of the base standard ISO/IEC 14443-2.

NOTE 1 The low EMD time $t_{E,PICC}$ is a function of FDT as defined in Amd.4 of ISO/IEC 14443-3.

NOTE 2 The EMD limit $V_{E,\ PICC}$ is a function of the field strength.

7.2.2.2 Noise requirements

In order to ensure a high dynamic range and sufficient sensitivity to EMD, the noise floor precondition test, defined in 5.2.3 shall be performed before this test.

7.2.2.3 Test commands

The PICC EMD test shall be performed for each ISO/IEC 14443-3 command. Depending on PICC application, additional higher layer commands shall be included in the test plan.

7.2.2.4 Test procedure

This test shall be done at least applying H_{min} and $H_{max.}$ Using the test PCD assembly, perform the following steps:

a) Adjust the RF power delivered by the signal generator to the test PCD antenna to the required field strength as measured by the calibration coil.

b) The PICC under test shall be placed in the DUT position. The RF drive into the test PCD antenna shall be readjusted to the required field strength if necessary.

c) Reset the PICC by switching the RF field off and on; then if necessary send a transition of sequence commands to put the PICC in the Test Initial State.

d) Send the command to be tested.

e) Record the sense coil's signal for a time period of at least 200 µs before the start of PICC subcarrier generation and at least 50 µs after.

f) Determine the value of $t_{E,PICC}$ from the acquired signal: if the PCD modulation is present on the trace then measure the time between the last rising edge of PCD modulation and the start of PICC subcarrier generation and calculate $t_{E,PICC}$ with the formula given in Amd.4 of ISO/IEC 14443-3; if the PCD modulation is not present on the trace then $t_{E,PICC}$ equals its maximum value defined in Amd.4 of ISO/IEC 14443-3.

g) Compute the signal power at the frequencies *fc* + *fs* and *fc* − *fs* as a function of time as defined in 5.2.2.

h) Using data obtained in step g), determine the time t_{START} corresponding to half the upper side band amplitude during the rising edge of PICC transmission. Take note of the maximum value of the upper side band amplitude during the time period [t_{START} - $t_{E,PICC}$; t_{START} - 10/*fc*]. If this value is smaller than $V_{E,PICC}$ then the test passes. If this value is greater or equal than four times the value of $V_{E,PICC}$ then the test fails. If the value is in between then check that the signal amplitude never exceeds $V_{E,PICC}$ for a time period greater than 16/*fc*.

i) Repeat step h) for the lower side band frequency.

j) Repeat step d) to step i) for the next test command.

7.2.2.5 Test report

The test report shall state whether the PICC EMD level during $t_{E,PICC}$ was below $V_{E,PICC}$ as well as compliant with the exceptions defined in Amd.4 of ISO/IEC 14443-3.

Furthermore the test report shall give the measured maximum electromagnetic disturbance levels of the upper and lower sidebands at *fc* + *fs* and *fc* − *fs* during $t_{E,PICC}$. A graph showing EMD levels during $t_{E,PICC}$ should be incorporated in the report in case the test fails.

Page 194, ANNEX I

Add new ANNEX I (remove "removed"):

(Informative)

The following code in C language may be used to perform the EMD level measurements.

```
/*************************************************************/
/***  This program calculates the Upper Side band (USB) and  ***/
/***  Lower side band (LSB) Load Modulation Amplitudes       ***/
/***  versus time of a PICC for the evaluation of EMD levels ***/
/***  according to ISO/IEC 10373-6                           ***/
/*************************************************************/
/*** Input:                                                 ***/
/***  File in CSV Format containing a table of two          ***/
/***  columns (time and sense coils' voltage)               ***/
/***                                                        ***/
/***  data format of input-file:                            ***/
/***  -------------------------                             ***/
/***  - one data-point per line:                            ***/
/***    (time[seconds], sense-coil-voltage[volts])          ***/
/***  - contents in ASCII, no headers                       ***/
/***  - data-points shall be equidistant time               ***/
/***  - minimum sampling rate: 100 MSamples/second          ***/
/***  - At least 200 microsecond before start of PICC       ***/
/***    sub-carrier generation                              ***/
/***  - At least 50 microsecond after start of PICC         ***/
/***    sub-carrier generation                              ***/
/***                                                        ***/
/***  example for spreadsheet file (start in next line):    ***/
/***   (time)     (voltage)                                 ***/
/***  3.00000e-06,1.00                                      ***/
/***  3.00200e-06,1.01                                      ***/
/***  .....                                                 ***/
/***                                                        ***/
```

```
/***  Ouput:                                          ***/
/***  File in CSV Format containing the results       ***/
/***  in a table of three columns (time, USB, LSB)    ***/
/***                                                  ***/
/***                                                  ***/
/*************************************************************/
/*** RUN:                                           ***/
/***  "exefilename" filename[.csv]                   ***/
/*************************************************************/
/*** ISO/IEC 10373-6 EMD levels Calculation         ***/
/*** Program Version 1.0     Release January 2010   ***/
/*************************************************************/

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>

#define MAX_SAMPLES 5000000
#define MAX_LMA 100000

/*** Declare function prototype ***/
int File_info(char *  , double *);
int readcsv(char * ,double * ,double * );
int writecsv(char* ,int ,double * ,double * ,double * );
int Sliding_LMA(double ,int ,double *,double *,int ,double *,double *,double *);
void Noise_STD(int ,double *,double *, double *,double *);


/*************************************************************/
/***    File_info  function                          ***/
/***                                                 ***/
/***    Description:                                 ***/
/***    This function parse a file in CSV format     ***/
/***    to determine the number of lines and sample rate  ***/
/***                                                 ***/
/***    Input: filename                              ***/
/***                                                 ***/
/***    Return: Number of samples  (sample Count)    ***/
/***           0  if an error occurred               ***/
/***                                                 ***/
/*************************************************************/
int File_info(char * fname , double * pdt)
{
      int i , c;
      double t1,v1,t2,v2;
      FILE     *sample_file;

  /************ Open File ***********************************/
  if (!strchr(fname, '.'))   strcat(fname, ".csv");

  if ((sample_file = fopen(fname, "r"))== NULL)
  {
        printf("Cannot open input file %s.\n",fname);
     return 0;
   }
     /*** Read two first lines to retrieve sample rate ***/
   fscanf(sample_file,"%Lf,%Lf\n", &t1, &v1);
     if (feof(sample_file))
     {
           fclose(sample_file);
```

```
            return 0;
        }
        fscanf(sample_file,"%Lf,%Lf\n", &t2, &v2);
        if (feof(sample_file))
        {
            fclose(sample_file);
            return 0;
        }
        *pdt=t2-t1;

        i=2;

        while (!feof(sample_file))
        {
            c = fgetc(sample_file);
            if (c == '\n')
            {
                i++;
                if (i>=MAX_SAMPLES)
                {
                    printf("Too many samples in input file: only %d samples retained\n",i);
                    break;
                }
            }
        }
        fclose(sample_file);
        return i;
}


 /*************************************************************/
/***    Read CSV File  Function                          ***/
/***                                              ***/
/***    Description:                                ***/
/***    This function reads the table of time and sense coil ***/
/***    voltage from a File in CSV Format                ***/
/***                                              ***/
/***    Input: filename                             ***/
/***                                              ***/
/***    Return: Number of samples  (sample Count)        ***/
/***          0  if an error occurred                ***/
/***                                              ***/
/***    Displays Statistics:                        ***/
/***                                              ***/
/***    Filename, SampleCount, Sample rate, Max/Min Voltage  ***/
/*************************************************************/

int readcsv(char* fname,double vtime[],double vd[])
{
  double max_vd,min_vd;
  int i;

  FILE     *sample_file;

  /************ Open File *********************************/
  if (!strchr(fname, '.'))   strcat(fname, ".csv");

  if ((sample_file = fopen(fname, "r"))== NULL)
    {
        printf("Cannot open input file %s.\n",fname);
        return 0;
```

```
    }
  /*************************************************************/
  /* Read CSV File                                             */
  /*************************************************************/
  max_vd=-1e-9F;
  min_vd=-max_vd;
  i=0;

  while (!feof(sample_file))
    {
          if (i>=MAX_SAMPLES)
     {
          printf("Too many samples in input file: only %d samples read\n",i);
      break;
      }
    fscanf(sample_file,"%lf,%lf\n", &vtime[i], &vd[i]);
    if (vd[i]>max_vd) max_vd=vd[i];
    if (vd[i]<min_vd) min_vd=vd[i];
    i++;
    }
  fclose(sample_file);

  /************ Displays Statistics  ************************/
  printf("\n***********************************************\n");

  printf("Statistics: \n");
  printf(" Filename    : %s\n",fname);
  printf(" Sample count: %d\n",i);
  printf(" Sample rate : %1.0f MHz\n",1e-6/(vtime[1]-vtime[0]));
  printf(" Max(vd)     : %4.0f mV\n",max_vd*1000);
  printf(" Min(vd)     : %4.0f mV\n",min_vd*1000);
  return i;
}/*************** End ReadCsv ***************/

/*****************************************************************/
/***    Write CSV File  Function                               ***/
/***                                                           ***/
/***    Description:                                           ***/
/***    This function writes in a CSV format file              ***/
/***    the result of LMA coputation:                          ***/
/***    Fist column   = time(s)                                ***/
/***    Second column = Upper side band amplitude (V)          ***/
/***    Third column  = Lower side band amplitude (V)          ***/
/***                                                           ***/
/***    Return: Number of written samples                      ***/
/***            0  if an error occurred                        ***/
/*****************************************************************/

 int writecsv(char* fname,int n_LMA,double LMA_time[],double USB[],double LSB[])
 {
       int i;
       FILE     *out_file;
       if ((out_file = fopen(fname, "w"))== NULL)
     {
          printf("Cannot open output file %s.\n",fname);
          return 0;
     }
       for (i=0;i<n_LMA;i++)
       {
            fprintf(out_file,"%7.4E,%7.4E,%7.4E\n",LMA_time[i],USB[i],LSB[i]);
       }
```

```
    fclose(out_file);
    return i;
}

/*****************************************************************/
/***    Sliding_LMA : Load Modulation Amplitude vs Time      ***/
/*****************************************************************/
/***    Description:                                          ***/
/***    This function calculates Upper side band and          ***/
/***    Lower side band amplitudes  as a function of time     ***/
/***                                                          ***/
/***    Arguments:                                            ***/
/***    fc = carrier frequency (Hz)                           ***/
/***    count = number of input signal samples                ***/
/***    vtime[] = input signal time array                     ***/
/***    vd[] =   input signal voltage array                   ***/
/***    lout =   max. size of following arrays                ***/
/***    LMA_time[] = Times to which LMAs are computed         ***/
/***    USB[] = load modulation amplitude at fc+fs            ***/
/***    LSB[] = load modulation amplitude at fc-fs            ***/
/***                                                          ***/
/***    return value: number of computed LMA                  ***/
/*****************************************************************/
int Sliding_LMA(double fc,int count,double vtime[],double vd[],int lout,double LMA_time[],double USB[],double
LSB[])
{
    double c1_real,c1_imag;
    double c2_real,c2_imag;
    double w0,wu,wl,dt;
    double Wb;                  /* Bartlett window coefficient */
    int i,j,k=0;
    int N_data;          /* Time window size*/
    int N_over;          /* Overlap */
    int N_middle;            /* Half window size */
    double *Yuc,*Yus,*Ylc,*Yls; /* Phase factors */
    double  pi;   /* pi=3.14.... */
    double sum_Wb=0; /* Sum of Bartlett coeff. */
    double cf; /* correction factor of the Bartlett window */

  pi = (double)atan(1.0)*4; /* calculate pi */

    w0=(double)(fc*2.0)*pi; /* carrier 13.56 MHz */
    wu=(double)(1.0+1.0/16.0)*w0; /* upper sideband 14.41 MHz */
    wl=(double)(1.0-1.0/16.0)*w0; /* lower sideband 12.71 MHz */


    /********** Time window *****************************/
    dt=vtime[2]-vtime[1]; /* Note: (vtime[2]-vtime[1]) is the scope sample rate */
    N_data=(int)(0.5+2*16.0F/dt/fc); /* Number of samples for two subcarrier periods */
    N_middle=(int) (0.5+N_data/2);
    N_over=(int) (0.5+1.0/dt/fc); /* Overlap of 1/fc */

    /******* Allocate memory ****************************/
    Yuc=(double *) malloc(N_data * sizeof(double));
    if (Yuc == NULL)
    {
        printf("Cannot allocate memory");
        return 0;
    }
    Yus=(double *) malloc(N_data * sizeof(double));
    if (Yus == NULL)
```

```
{
      printf("Cannot allocate memory");
      free(Yuc);
      return 0;
}
Ylc=(double *) malloc(N_data * sizeof(double));
if (Ylc == NULL)
{
      printf("Cannot allocate memory");
      free(Yuc); free(Yus);
      return 0;
}
Yls=(double *) malloc(N_data * sizeof(double));
if (Yls == NULL)
{
      printf("Cannot allocate memory");
      free(Yuc); free(Yus); free(Ylc);
      return 0;
}

/************* Calculate apodization window and phase factors ********/
for( i=0;i<N_data;i++)
      {
            /* Bartlett window */
            if ((N_data & 1) == 0)
            {
                  /* N_data is even */
                  if (i < (int) (N_data /2))
                  {
                        Wb=2.0F*i/(double)(N_data - 1);
                  }
                  else
                  {
                        Wb=2.0F*(N_data-i-1)/(double)(N_data - 1);
                  }
            }
            else
            {
                  /*N_data is odd */
                  if (i <= (int) (0.001+(N_data-1) /2))
                  {
                        Wb=2.0F*i/(double)(N_data - 1);
                  }
                  else
                  {
                        Wb=2.0F-2.0F*i/(double)(N_data - 1);
                  }

            }
            Yuc[i]=(double)cos(wu*i*dt)*Wb;
            Yus[i]=(double)sin(wu*i*dt)*Wb;
            Ylc[i]=(double)cos(wl*i*dt)*Wb;
            Yls[i]=(double)sin(wl*i*dt)*Wb;
            sum_Wb += Wb;
      }
      cf=N_data/sum_Wb;

/****************** DFT ******************************/

for (j=0;j<count-N_data;j=j+N_over)
{
```

```
        c1_real=0; /* real part of the up. sideband fourier coefficient */
        c1_imag=0; /* imag part of the up. sideband fourier coefficient */
        c2_real=0; /* real part of the lo. sideband fourier coefficient */
        c2_imag=0; /* imag part of the lo. sideband fourier coefficient */

        for( i=0;i<N_data;i++)
        {
            c1_real=c1_real+vd[i+j]*Yuc[i];
            c1_imag=c1_imag+vd[i+j]*Yus[i];
            c2_real=c2_real+vd[i+j]*Ylc[i];
            c2_imag=c2_imag+vd[i+j]*Yls[i];

        }

        /****************** DFT scale ************************/

        c1_real=2.0F*cf*c1_real/(double) N_data;
        c1_imag=2.0F*cf*c1_imag/(double) N_data;
        c2_real=2.0F*cf*c2_real/(double) N_data;
        c2_imag=2.0F*cf*c2_imag/(double) N_data;

        /*************** absolute fourier coefficient **********/
        USB[k]=(double)sqrt(c1_real*c1_real + c1_imag*c1_imag);
        LSB[k]=(double)sqrt(c2_real*c2_real+c2_imag*c2_imag);

        /************** Half window time ***********************/
        LMA_time[k]=vtime[j+N_middle];   /* Half window time */
        k++;
        if (k > lout) break; /* stop if array size is reached*/
    }

    free(Yuc);
    free(Yus);
    free(Ylc);
    free(Yls);
    return k;

}/*************** End DFT ***************/

/*****************************************************************/
/***    Noise_STD : Noise standard deviation                   ***/
/*****************************************************************/
/***    Description:                                           ***/
/***    This function calculates the standard deviations       ***/
/***    at fc+fs and fc-fs as required by the noise            ***/
/***    precondition test of ISO/IEC 10373-6.                  ***/
/***    Results are meaningful only when the sense coil's      ***/
/***    signal is recorded with a reference PICC.              ***/
/***                                                           ***/
/***    Arguments:                                             ***/
/***    n_LMA = number of input values                         ***/
/***    USB[] = load modulation amplitude at fc+fs             ***/
/***    LSB[] = load modulation amplitude at fc-fs             ***/
/***    pSTD_USB= standard deviation at fc+fs                  ***/
/***    pSTD_LSB= standard deviation at fc-fs                  ***/
/***                                                           ***/
/*****************************************************************/
void Noise_STD(int n_LMA,double USB[],double LSB[], double *pSTD_USB,double *pSTD_LSB)
{
    double P_USB=0,P_LSB=0;
    int i;
```

```
    /*************** Square summation *********************/
    for( i=0;i<n_LMA;i++)
    {
        P_USB += USB[i]*USB[i];
        P_LSB += LSB[i]*LSB[i];
    }
    *pSTD_USB=sqrt(P_USB/n_LMA);
    *pSTD_LSB=sqrt(P_LSB/n_LMA);

}

/*****************************************************************/
/***    MAIN  Program                                          ***/
/*****************************************************************/
int main(int argc, char *argv[])
{
    char fname[256];
    char fout[256];
    int sample_count;
    int lout;        /*Maximun length of result arrays */
    int n_LMA;       /* Number of computed LMA */
    int status;
    double fc;                  /* Carrier frequency */
    double std_USB,std_LSB,dt;
    double *pTime, *pVolts, *pLMA_time, *pUSB, *pLSB;

    fc=13.56e6;

    printf("\n");
    printf("************************************************\n");
    printf("**** ISO/IEC 10373-6 EMD Test-Program      ****\n");
    printf("**** Version: 1.0 January 2010             ****\n");
    printf("****                                       ****\n");
    printf("************************************************\n");

    if (argc > 1)
    {
        /*** First input parameter is taken as input file name ***/
        strcpy(fname, argv[1]);
    }
    else
    {
        /*** No input parameter ***/
        printf("\nCSV File name :");
        scanf("%s",fname);
    }

    if (!strchr(fname, '.'))   strcat(fname, ".csv");
    if (!(sample_count=File_info(fname , &dt))) return 0;
    lout= (int) (sample_count/(int)(0.5+1.0/dt/fc));
    if (lout > MAX_LMA) lout = MAX_LMA;

    /***          Start of memory allocation               ***/
    pTime= (double *) malloc(sample_count * sizeof(double));
    if (pTime == NULL)
    {
        printf("Cannot allocate memory");
        return 0;
    }
    pVolts= (double *) malloc(sample_count * sizeof(double));
```

```
    if (pVolts == NULL)
    {
        printf("Cannot allocate memory");
        free(pTime);
        return 0;
    }
    pUSB= (double *) malloc(lout * sizeof(double));
    if (pUSB == NULL)
    {
        printf("Cannot allocate memory");
        free(pTime); free(pVolts);
        return 0;
    }
    pLSB= (double *) malloc(lout * sizeof(double));
    if (pLSB == NULL)
    {
        printf("Cannot allocate memory");
        free(pTime); free(pVolts); free(pUSB);
        return 0;
    }
    pLMA_time= (double *) malloc(lout * sizeof(double));
    if (pLMA_time == NULL)
    {
        printf("Cannot allocate memory");
        free(pTime); free(pVolts); free(pUSB); free(pLSB);
        return 0;
    }
    /***        End of memory allocation        ***/

    if (!(sample_count=readcsv(fname,pTime,pVolts))) return 0; /* reading data */
    if   (!(n_LMA=Sliding_LMA(fc,sample_count,pTime,pVolts,lout,pLMA_time,pUSB,pLSB)))   return   0;   /*
processing data */
    strcpy(fout,"LMA_");
    strcat(fout,fname);
    status=writecsv(fout,n_LMA,pLMA_time,pUSB,pLSB); /* writing results in a file */

    Noise_STD(n_LMA,pUSB,pLSB,&std_USB,&std_LSB);  /* evaluating noise floor */

    /************** Result Display *************************/
    printf("\n");
    printf("************************************************\n");
    printf("Noise floor : \n");
    printf(" standard deviation at fc+fs: %7.3f mV\n",std_USB*1000);
    printf(" standard deviation at fc-fs: %7.3f mV\n",std_LSB*1000);
    printf("Note: Displayed results are meaningful only when\n");
    printf("      the sense coil's signal is recorded with a\n");
    printf("      reference PICC.");
    printf("\n************************************************\n");

    free(pTime);
    free(pVolts);
    free(pLMA_time);
    free(pUSB);
    free(pLSB);

    return 1;
}/*********************** End Main  *************************/
```