

Report - Paper - Technical Document Writing

HTE - 08.08.2013

1. Basics

In engineering, very often, we need to document our findings, transmit our knowledge and results to the general public. This calls for writing reports and documents which have more or less the same content and follow similar order of text.

Such a report should be structured according to following guidelines.

- a) It should be sectioned such as in the forward order of Abstract, Introduction, Theoretical Formulation, (Experimental) Results, Conclusion, Acknowledgement, References, Figures (Graphs) and Tables. In ECE 491 and 492 (Final Year Projects), the section titles and their orders are slightly different, i.e. they go as Abstract, Introduction, Materials and Methods, Results, Discussions, Conclusion, Acknowledgement, References. This subject will be elaborated more in the next section.
- b) It should be concise. In this sense it should avoid artistic and lengthy descriptions. It should be short, not containing repetitions.
- c) The sentences (in the same section) should in general follow a downward logical order. This means every sentence should be properly connected to the previous one.
- d) The naming of variables, parameters should be consistent all thought the text.
- e) The use of mathematical symbols should be consistent all throughout the text.
- f) The figures, tables and references should all be cited within the main text.
- g) The ambiguity is not allowed. Every sentence should be expressed with certainty.
- h) The figures, tables should be labelled properly and should be clear as far as possible.
- i) In summary, we should write a report in a format such that the reader does not have to contact us for general explanations.

2. Sections of a Report

The sections (parts) of a report are

- 1) Title of the report : The title should reflect the content of the report in a narrative manner.
- 2) Names of authors, their affiliations and contact details : This section gives the names and the surnames of the authors sometimes in the order of contribution amounts, their institutional addresses (affiliations) and contact details.
- 3) Abstract : This section gives the very short summary of the report, the subject of investigation, the methods used in carrying out this investigation, the results, important findings. All these should be expressed preferably in short and clear sentences so that the reader can get a general idea about the report without having to read the rest of the report.
- 4) Introduction : This section should introduce the subject investigated, the motivation (reason) behind the study, the previous work undertaken in this area with the clear citing (referencing) of existing literature and the originality of the present study.

- 5) Theoretical formulation or Description of experimental setup : In this section, we develop the theoretical formulation, from known (existing) results, numbering the equations in order, defining all parameters used, observing the rules of consistency, so that same symbols are not used for two different variables, functions, the symbols are recalled with the same name all throughout the text. If the study is of experimental nature, we describe experimental setup and state the measures taken to eliminate the effects of those parameters, variations likely to shadow the desired results of the present study. Preferably a photo and a schematic view of the experimental setup should be included.
- 6) Results and discussions : Based on the previous section, this section gives the results in the form of graphs, tables labelling all the curves and the parameters leaving no ambiguity. The results are discussed, stressing the consistency of those known parts with the existing literature and more importantly highlighting those points, where our results are more favourable than those in the existing literature. This way, comparison of own results and with those in the literature are made.
- 7) Conclusion : The important findings of the work are summarized, sometimes future work as an extension of the present study is stated. This section somewhat overlaps with Abstract.
- 8) Acknowledgement : This section cites the funding institution, if there is any, those who have helped the present study or those who have allowed the use of their facilities for the present study.
- 9) References : Usually in the form of numbers that follow the order of the downward flow of the main text, references provide those written, published, sometimes unpublished sources which have relevance to the present study. Their writings are specific to the publisher or the organizer (recipient) of the study. In all cases however, references should contain the name of authors of the work, its title, its publication details such as volume, issue and page numbers, year of publication, publisher. In short, it should contain enough details, so that the particularly cited reference can be found in the libraries, on the internet and so on.

It is important to point out that we normally start a study by first tackling the sections of Introduction, Theoretical formulation and Results and discussions. Abstract and Conclusion are written at the end.

Now, we turn to an example.

Example 2.1 : We use the file named, "A87_HygG beam in turbulence_HTE_YC_OC_2012", also available on the course webpage. This document is a scientific paper published in a journal, named "Optics Communications", volume 285, issues 21-22, pages 4194-4199, in the year 2012. Below, we just name it as "paper".

From the examination of this file, we note the followings

- 1) Title of the paper is "Hypergeometric Gaussian beam and its propagation in turbulence". From this title, we understand that, this paper (work) takes an (optical) beam, named "Hypergeometric Gaussian beam" and examines its propagation characteristics through (atmospheric) turbulence.
- 2) Names of authors, are given as "Halil Tanyer Eyyubođlu" (first, main author) and "Yangjian Cai" (second, co-author). From the ordering we understand that the first author has contributed more to this study. The affiliations are "Çankaya University, Electronic and

Communication Engineering Department, Eskişehir yolu 29. km, Yenimahalle, 06810 Ankara, Turkey. " and "2School of Physical Science and Technology, Soochow University, Suzhou 215006, China". The contact details are " Phone: (+90) 312-2331322, Fax: (+90) 312-2848043, e-mail: h.eyyuboglu@cankaya.edu.tr". First author is given as the corresponding author.

- 3) The abstract goes as "We study propagation characteristics of hypergeometric Gaussian beam in turbulence. In this context, we formulate the receiver plane intensity using extended Huygens-Fresnel integral. From the graphical results, it is seen that, after propagation, hypergeometric Gaussian will in general assume the shape of a dark hollow beam at topological charges other than zero. Increasing values of topological charge will make the beam broader with steeper walls. On the other hand, higher values of hollowness parameter will contract into a narrower shape. Raising the topological charge or the hollowness parameter individually will cause outer rings to appear. Both increased levels of turbulence and longer propagation distances will accelerate the beam evolution and help reach the final Gaussian shape sooner. At lower wavelengths, there will be less beam spreading." As seen from the sentences of the abstract are short, concise and express the findings without repetitions.
- 4) In the introduction section, we firstly explain how Hypergeometric Gaussian beam comes about, then list the previously undertaken work by citing nine references, i.e., [1] to [9]. Eventually we end this section by mentioning, in the last paragraph, our reasons of performing this study and its originality.
- 5) Theoretical formulation section is entitled as, "Formulation of hypergeometric Gaussian beam on source and receiver planes". Six equations are stated during the formulation development with each one connected to the previous one in a downward logical manner, with all parameters being defined. Let's if this is the case by examining Eq. (3), which is reprinted below.

$$\begin{aligned}
 R_r(r, \phi) = & \frac{\pi \Gamma(0.5n + 0.5p + 0.5ja + 1)}{\lambda^{0.5n-0.5p-0.5ja+1} n!} \frac{\alpha_s^{n+p+ja+2} \rho_t^{-n+p+ja+2} D^{-0.5n+0.5p+0.5ja-1}}{(\lambda \rho_t^2 D - j\pi \rho_t^2 \alpha_s^2 + \lambda \alpha_s^2 D)^{0.5n+0.5p+0.5ja+1}} \\
 & \times \int_0^\infty \int_0^{2\pi} s_2 [\lambda D s_2 \exp(-j\theta_2) - j\pi \rho_t^2 r \exp(-j\phi)]^n {}_1F_1[[0.5n + 0.5p + 0.5ja + 1, n + 1, -z] \\
 & \times \exp\left\{-\frac{s_2^2}{\rho_t^2} - \frac{s_2^2}{\alpha_s^2} + jn\theta_2 + \frac{j\pi}{\lambda D} [2rs_2 \cos(\phi - \theta_2) - s_2^2]\right\} ds_2 d\theta_2 \quad (2.1)
 \end{aligned}$$

For this equation, we try to assess whether all mathematical symbols are defined in the text. In (1) below, we do this one by one and indicate where the definition is placed in the text.

$R_r(r, \phi)$: R_r is defined as average intensity above Eq. (2). The function variables, r, ϕ are left undefined. r, ϕ are understood to be the transverse receiver plane coordinates from the first paragraph of section 3. Results and discussions.

π : The geometric pi number. Since known universally, no definition is needed.

$\Gamma(0.5n + 0.5p + 0.5ja + 1)$: Γ is Gamma function, but its definition is not made.

from the first paragraph of section 3. Results and discussions, we understand that this is the case. n is the topological charge, p and a are the hollowness parameters. n, p and a are all defined underneath Eq. (1).

α_s : The Gaussian source size of the beam. Defined underneath Eq. (1).

ρ_t : Coherence length of spherical wave. Defined underneath Eq. (2).

D : The distance between the source (transmitter) and receiver.

Defined underneath Eq. (2).

λ : Wavelegh of the beam, defined underneath Eq. (2).

j : Imaginary number, $\sqrt{-1}$, not defined, since known universally.

s_2 : Radial source plane coordinate. Defined underneath Eq. (1).

θ_2 : Angular source plane coordinate. Defined underneath Eq. (1).

Note that there are also, s_2 and θ_2 as written in Eq. (2). This is because we need two set of distinct coordinate points on the source plane. Hence they are subscripted with 1 and 2.

from the first paragraph of section 3. Results and discussions, we understand that this is the case.

${}_1F_1[[0.5n + 0.5p + 0.5ja + 1, n + 1, -z]$: ${}_1F_1$ is the confluent hypergeometric function.

Note that there are bracket errors in the writing of arguments for ${}_1F_1$. It should have been written as ${}_1F_1(0.5n + 0.5p + 0.5ja + 1, n + 1, -z)$.

z : This parameter is defined in Eq. (4).

- 6) Results and discussions section is named as such and contains the results obtained by using the theoretical formulation developed in the previous section. All the results are offered in the form of graphs and use the formulation given in Eq. (7) of this section. The two formulas stated in Eq. (7) are basically the normalized source and receiver plane intensities derived from Eqs. (1) and (5). In this section, there are discussions about the variation of the normalized source or receiver plane intensities with respect to source (n, p, λ) and propagation parameters (D, C_n^2). In this sense, we reproduce Fig. 4 below

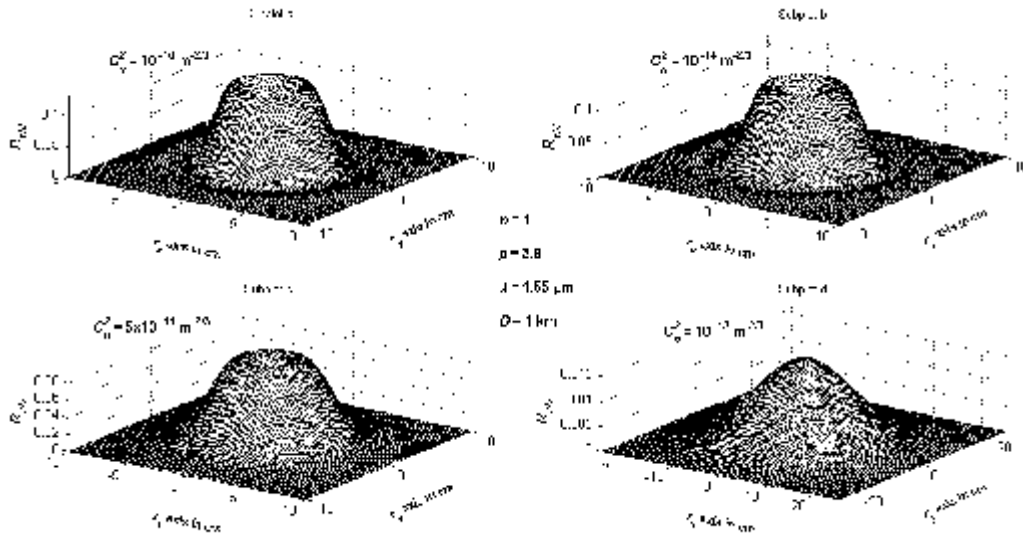


Fig. 2.1 Reproduction of Fig. 3 from the paper entitled, "Hypergeometric Gaussian beam and its propagation in turbulence".

As seen from Fig. 2.1, with increases in the propagation parameter, called structure constant, mathematically denoted by C_n^2 , the normalized receiver beam intensity denoted by R_{rN} changes in the manner that, the hollowness in the central part of the beam decreases and the beam profile approaches that of a Gaussian (bell) shape. In this figure, to observe the variations against C_n^2 , other parameters, namely, n , p , λ , D are held at the constant numeric settings given in the middle of this figure. It is possible to find these comments in the fifth paragraph of this section. Additionally in the last sentence of the same paragraph, we say that such observations are in agreement with existing literature by giving references 13 and 14.

- 7) Conclusion : This section summarizes the important findings of the previous section also some future work is proposed.
- 8) Acknowledgement : In this particular paper, this section only covers the second author.
- 9) As stated above there are several reference styles specific to the publisher. In this paper, the style is in the form of

First author's initials, first author's surname, second author's initials, second author's surname, ..., journal name (in full, not in abbreviation), volume number, (year of publication), starting page number.

Note that for books and conference papers this style will be different.

Exercise 2.1 : For Eq. (7) of the paper entitled, "Hypergeometric Gaussian beam and its propagation in turbulence", check if all functions, parameters are defined in the text, write their locations. Make comments whether there are any typing corrections that can be applied to Eq. (7) or omissions in definitions. Eq. (7) is reprinted below

$$S_{sN}(s, \theta) = \frac{|u_s(s, \theta)|^2}{\max[|u_s(s, \theta)|^2]}, \quad R_{rN}(r, \phi) = \frac{R_r(r, \phi)}{\max[|u_s(s, \theta)|^2]} \quad (2.2)$$

Hint : Use the procedure followed above for Eq. (3).

Exercise 2.2 : For Fig. 5 of the paper entitled, "Hypergeometric Gaussian beam and its propagation in turbulence", check if all parameters are defined in the text, write their locations. Further check if there are any ambiguities in the figure. Comment on the dependence of R_{rN} (vertical axis) in different curves (in total there are 8 curves) on the radial distance parameter, r (on horizontal axis). Fig. 5 of the paper is reproduced below as Fig. 2.2.

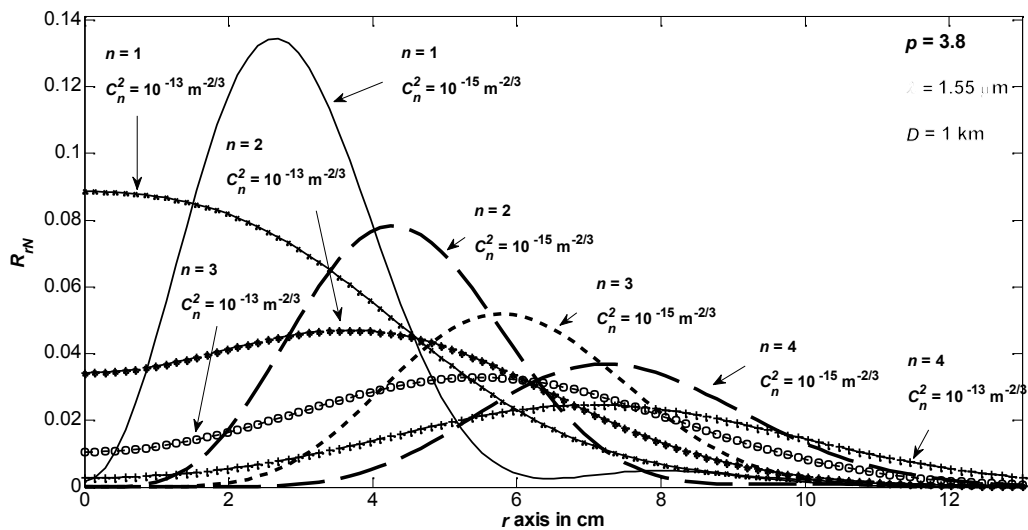


Fig. 2.2 Fig. 5 of the paper examined in Example 2.1, Exercise 2.1 and 2.2.

3. Writing a Complete Report Right From the Beginning

In this section, we give the stages of writing a simple report. To this end, we are asked to investigate the properties, the dependence of the Bessel function of first kind, mathematically denoted as $J_\nu(z)$ on its parameters, namely, ν , known as the order and z , known as the argument. It is further requested that our report should contain the computational and symbolic capabilities of Matlab for this function.

Firstly, we do some search (even on internet via the <http://scholar.google.com.tr>) to find resources, references we can benefit from, we get the followings

- 1) L. C. Andrews and R. L. Phillips, Mathematical Techniques for Engineers and Scientists, SPIE Press, Bellingham, 2002.
- 2) M. Abramowitz and I. Stegun, Handbook of Mathematical Functions,, Dover Publications, New York, 1970.
- 3) I. S. Gradshteyn and I. M. Ryzhik, Tables of Integrals, Series and Products, Academic Press, New York, 2000.
- 4) Matlab 2012a.

In particular, these sources (books) are available in our university library.

We gather the following information.

Bessel function of first kind, $w = J_\nu(z)$ satisfies the following differential equation

$$\frac{d^2}{dz^2} w + z \frac{d}{dz} w + (z^2 - \nu^2) w = 0 \quad (3.1)$$

Usually, the order of this Bessel function integer, while is real, rather than complex, thus we replace $z \rightarrow x$, and $\nu \rightarrow n$, then $J_\nu(z)$ becomes $J_n(x)$. In Matlab $J_\nu(z)$ is available both numerically and symbolically (analytically)

By taking and $J_n(x)$ and plotting it for $n = 0, 1, 2, 3, 4$ and x being in the range $0 \rightarrow 15$, we get Fig. 3.1.

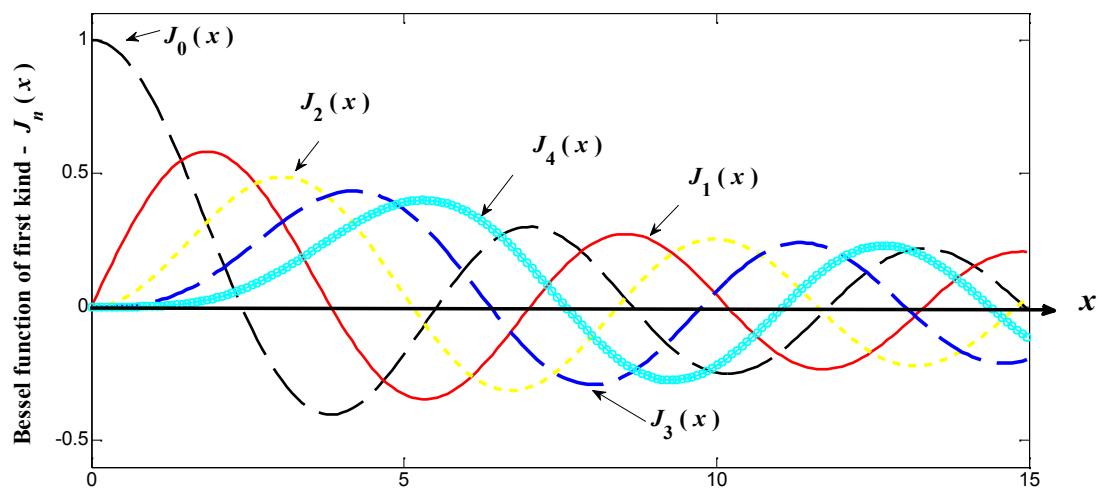


Fig. 3.1 Plots of Bessel functions $J_n(x)$ for $n = 0, 1, 2, 3, 4$.

Collecting other relevant data about $J_\nu(z)$, we write the following report.

4. Sample Report

Title : Investigation of Bessel function of first kind

Abstract : In this report, we investigate Bessel function of the first kind, symbolically denoted by $J_\nu(z)$, where ν is the order, while z is the argument. Our findings indicate that for integer orders and real arguments, Bessel functions of the first kind exhibit decaying oscillatory behaviour against the argument. At $z=0$, $J_0(z)$ assumes the numeric value of one, while all other higher orders start at zero. We also investigate the numeric and symbolic capabilities of Matlab for Bessel function of the first kind. There it is seen that Matlab is able to handle such operations in an accurate manner.

1. Introduction

Bessel functions are named for Friedrich Wilhelm Bessel (1784 - 1846), however, Daniel Bernoulli is generally credited with being the first to introduce the concept of Bessels functions in 1732 [1]. There are four types of Bessel functions, symbolically shown as $J_\nu(z)$, $I_\nu(z)$, $Y_\nu(z)$ and $K_\nu(z)$. In this study, we restrict ourselves to the one called the first kind, i.e., $J_\nu(z)$. There are several literature sources that describe in details the properties of Bessel function. Some of these are cited in [2-4]. In the field communications, the Bessel function of the first kind is used to represent propagation of waves in cylindrical geometries. One such example is optical fibre cable [5, 6].

The stable numeric computation of Bessel functions generally poses a problem, since they have infinite series expansions. Fortunately, this is handled by in Matlab in an accurate manner.

2. Theoretical background

It is known that Bessel function of the first kind, $w = J_\nu(z)$ satisfies the following second order differential equation [2-4]

$$\begin{aligned} \frac{d^2}{dz^2} w + z \frac{d}{dz} w + (z^2 - \nu^2) w &= 0 \\ \frac{d^2}{dz^2} J_\nu(z) + z \frac{d}{dz} J_\nu(z) + (z^2 - \nu^2) J_\nu(z) &= 0 \end{aligned} \quad (1)$$

Note that Bessel function, $Y_\nu(z)$ is also a solution to (1). Additionally by changing the sign of z^2 to $-z^2$, (1) becomes the differential equation for $I_\nu(z)$ and $K_\nu(z)$.

$J_\nu(z)$ has the following infinite series expansion

$$J_\nu(z) = (0.5z^2)^\nu \sum_{k=0}^{\infty} \frac{(-0.25z^2)^k}{k! \Gamma(\nu + k + 1)} \quad (2)$$

As seen from the expansion in (2), the successive terms will alternate in sign, causing oscillations, thus affecting the stability of the summation. For this reason, computing $J_\nu(z)$ from an integral expression is easier. Such a representation is given below

$$J_\nu(z) = \frac{2(0.5z)^\nu}{\pi^{0.5} \Gamma(\nu + 0.5)} \int_0^{2\pi} (1-t^2)^{\nu-0.5} \cos(zt) dt \quad (3)$$

Recurrence formulae establish relations between lower, higher orders and the derivatives. Two such formulae are

$$\begin{aligned} J_{\nu-1}(z) + J_{\nu+1}(z) &= \frac{2\nu}{z} J_\nu(z) \\ J_{\nu-1}(z) - J_{\nu+1}(z) &= 2 \frac{d}{dz} J_\nu(z) \end{aligned} \quad (4)$$

3. Results and discussions

In this section, we test formulations given in section 2, symbolically (analytically) or numerically.

First we test (1), for this we write the following Matlab code

```
clear all;clc ;close all;warning off all
syms nu z    %% Declaring symbolic variables
Jnuz = besselj(nu,z); %%% Defining J_nu(z)
Jnuz2 = diff(Jnuz,'z',2); %%% Second derivative of J_nu(z)
Jnuz1 = diff(Jnuz,'z'); %%% First derivative of J_nu(z)
DE = z^2*Jnuz2 + z*Jnuz1 + (z^2 - nu^2)*Jnuz; %%% Second order
differential equation
simplify(DE) %%% Simlifying the result, thus cancelling the same terms
```

Running this code gives

```
ans = 0
```

Hence we have successfully verified (1).

Since the summation in (2) has oscillatory nature , we skip it and test (3) with the following Matlab routine

```
function Besselintegral
clear;clc
global nu z
z = 2 + 3*j;nu = 4.2;tol = 1e-6;
format short e;altlim = 0;uslim = 1;
resj = besselj(nu,z) %%% Callin J_nu(z) from Matlab
inres = 2*(0.5*z)^nu/sqrt(pi)/gamma(nu + 0.5)*quade(@fun1,altlim,uslim,tol)
%% Evaluating the integral numerically
Err = resj - inres %%% Finding error
function y = fun1(t)
global nu z
y = (1 - t.^2).^ (nu - 0.5) .*cos(z*t);
```

Running the above gives

```
resj = -4.2922e-001 -1.9813e-001i
```

```
inres = -4.2922e-001 -1.9813e-001i
```

```
Err = 5.5511e-017 -2.4980e-016i
```

The value of Err on the last line demonstrates that the integral representation in (3) is able to evaluate Bessel function of the first kind at the machine accuracy level. Tests conducted at other orders and arguments show that this error does not deviate substantially.

Next the recurrence relations written in (4) are tested. This is done by the following Matlab code

```
Jnuzm1 = besselj(nu - 1,z); %%% Defining J_nu-1(z)
Jnuzp1 = besselj(nu + 1,z); %%% Defining J_nu+1(z)
Rec1 = Jnuzm1 + Jnuzp1 - 2*nu*Jnuz/z;Rec1 = simplify(Rec1) %%% First
recurrence in (4)
```

```
Rec2 = Jnuzm1 - Jnuzp1 - 2*Jnuz1;Rec2 = simplify(Rec2) %%% Second
recurrence in (4)
```

Note that since this code is written in the same Matlab m file as the one used in the test of (1), some common parameters are redefined. Running this code delivers

Rec1 = 0

Rec2 = 0

This way we have proven the recurrence relations in (4).

Finally we investigate the behaviour of Bessel function of the first kind against the changes in order and argument. For this we switch to integer order and real arguments. Thus plotting $J_n(x)$ for $n = 0, 1, 2, 3, 4$ with x being in the range $0 \rightarrow 15$, we get the curves of Fig. 1.

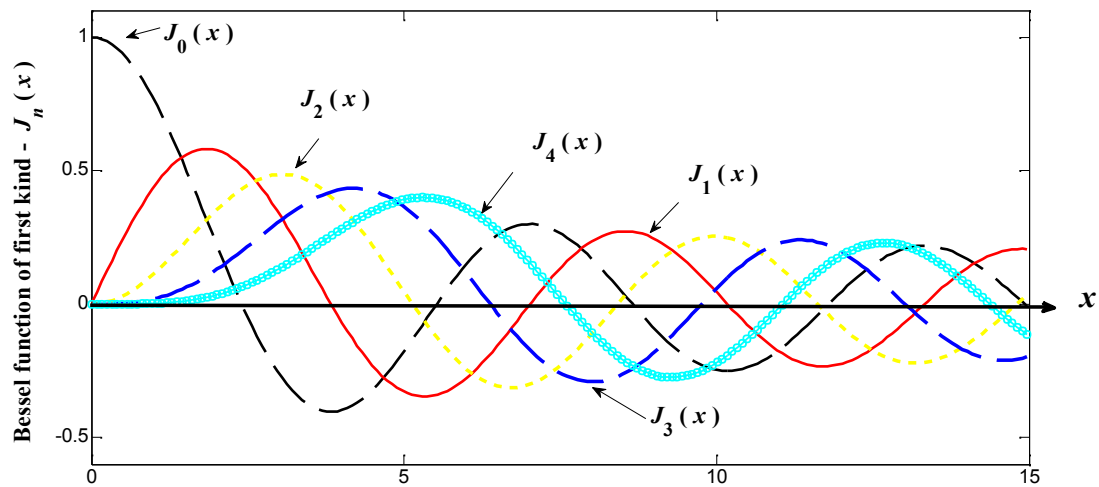


Fig. 1 Plots of Bessel function of first kind, $J_n(x)$ for $n = 0, 1, 2, 3, 4$ in the range $x = 0 \rightarrow 15$.

Fig. 1 demonstrates that for integer orders and real arguments, Bessel functions of the first kind exhibit decaying oscillatory behaviour against the argument. At $z = 0$, $J_0(z)$ assumes the numeric value of one, while other higher orders start at zero.

4. Conclusion

In this work, we have examined Bessel function of the first kind. It is seen that for integer orders and real arguments, this function exhibits decaying oscillatory behaviour against its argument. At $z = 0$, zeroth order assumes the numeric value of one, while other higher orders start at zero. The tests conducted in Matlab have shown that, we can numerically evaluate Bessel function of the first kind with high accuracy by integration method. Furthermore it was seen that the symbolic features of Matlab is able to deliver correct results when testing the Bessel differential equation and the recurrence relations.

References

- 1) Available at http://www.mhtlab.uwaterloo.ca/courses/me755/web_chap4.pdf, accessed on 10.10.2013
- 2) L. C. Andrews and R. L. Phillips, Mathematical Techniques for Engineers and Scientists, SPIE Press, Bellingham, 2002.
- 3) M. Abramowitz and I. Stegun, Handbook of Mathematical Functions,, Dover Publications, New York, 1970.
- 4) I. S. Gradshteyn and I. M. Ryzhik, Tables of Integrals, Series and Products, Academic Press, New York, 2000.
- 5) G. P. Agrawal, Fiber-Optic Communication Systems , John Wiley & Sons Inc., New York, 2002.
- 6) G. Keiser, "Optical Fiber Communications" 3nd Ed. 2000, McGraw Hill, ISBN : 0-07-116468-5.

5. Report Writing for ECE 491 and ECE 492

From the file, Bitirme_Projeleri_Sureci_2012_05.11.2012.pdf available at the link http://ece.cankaya.edu.tr/turkce/bitirmeprojectleri/Bitirme_Projeleri_Sureci_2012_05.11.2012.pdf, we have the following sample report for ECE 491 and ECE 492.

PROJECT NAME (ASSESSING THE PERFORMANCE OF TRANSDUCER X AS A TEMPERATURE MEASURING DEVICE)

Student Number(s) :

Supervisor(s) :

Report Date : DD,MM,YYYY

Abstract

In this project, our aim is to measure and display the resistance changes of transducer X against changes in temperature. In particular, we investigate whether this transducer exhibits a linear relationship between its resistance and temperature variations. From this investigation, it is concluded that transducer X can be used to measure temperatures between 0 to 25 °C with a root mean square error of 5.2 %.

Özet

Bu projede, bizim amacımız ...

1. Introduction

There are several transducers that can be used to measure temperatures as detailed in [1 – 3]. The accuracy for most of them cannot go above 93 %. Besides in those transducers, the range of linearity is often limited to 10 to 20 °C. Earlier experiments demonstrated that our recently designed transducer X could offer improved measuring accuracy and extended temperature range [4]. This part of the project is carried out to test the assertions in [4] and furthermore find the numeric values of temperature measuring accuracy and temperature measuring range of transducer X.

2. Materials and Methos

The experimental setup is shown in Figure 1. To establish better conduct between the transducer X and the temperature of the environment to be measured, we immersed transducer X into cubic water tank having side dimensions of 20 cm. The water tank was heated and cooled from underneath. Into the same tank, we placed water proof thermometer which acted as calibrator and reference device. From the manufacturer's data sheet [5], it is known that this waterproof thermometer has temperature range of -10 to 70 °C and a reading accuracy of 99.2 %. Measurements were taken every other two days and this was repeated twenty times. It is known that transducer X converts temperature changes into resistance changes [4]. To measure these changes, a voltmeter placed around the load resistor of the driving circuitry as shown in Figure 1.

3. Results

Data collected from the experimental setup is displayed in Figure 2, where the horizontal axis, T represents the temperature readings, taken from the thermometer, while the vertical axis, V_L gives the voltage readings across the load resistor, R_L which in turn gives an indication of the resistance changes in transducer X. In Figure 2, the averaged V_L readings taken at 1 °C intervals are marked as stars, then a straight line (i.e. a first order polynomial function) is fitted to these readings. The fitted line is described by the equation

$$V_s(T) = A + BT \quad (1)$$

Here it is seen that the stars are best concentrated around fitted line in the temperature range 0 to 25 °C. Hence if transducer X, were to be used for measuring temperature in this range, the root mean square error would be

$$E_{rms} = \left\{ \sum_{i=0}^{20} [V_{L_i} - V_s(T)]^2 \right\}^{0.5} \quad (2)$$

By inserting the values from (1) and from Figure 2 in (2), we find

$$E_{rms} = 0.052 \quad (3)$$

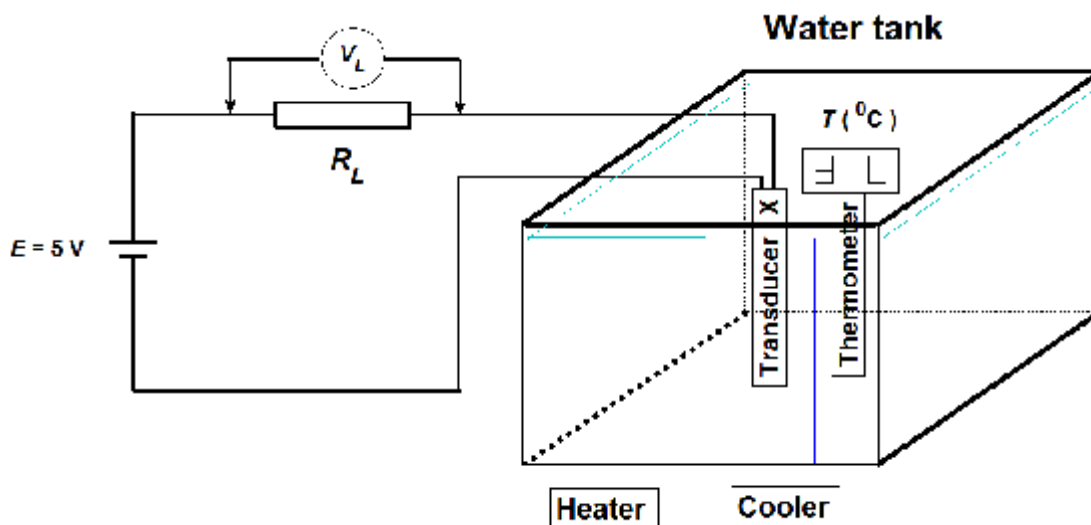


Figure 1 Schematic view of experimental setup.

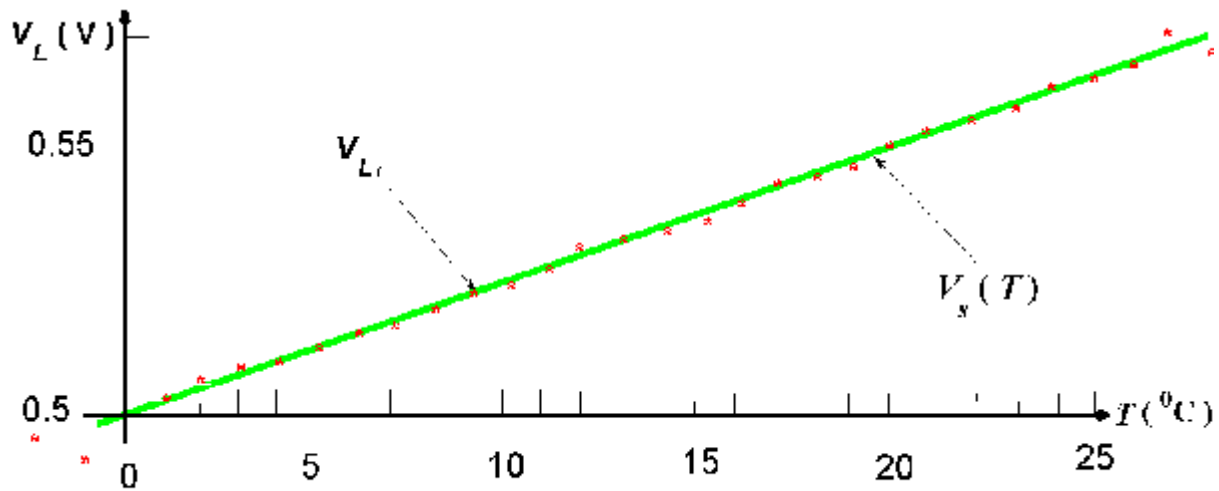


Figure 2 The variation of the voltage across the load resistor against temperature.

4. Discussions

From Figure 1, it seems that transducer X can be safely used as a temperature measuring device within temperature range of 0 to 25 $^{\circ}\text{C}$. In this range root mean square error is 5.2 %. To ensure the reliability of results, measurements were spread over twenty days with one day interval. Water tank was employed to establish better conduct with the reference thermometer and temperature of the environment. It is suggested as future study to repeat these measurements in air, to see if any differences arise.

5. Conclusion

We have assessed the suitability of transducer X for temperature measurements. It is found that this transducer can be used for this purpose within temperature range of 0 to 25 $^{\circ}\text{C}$, where root mean square error of the measurements will be 5.2 %.

6. Acknowledgements

We would like to thank our supervisor H. T. Eyyubođlu, for his guidance and help throughout the project. We further like to thank technicians N. Aybak, O. Yurdakul for the preparation of experimental setup.

7. References

- [1]. Book Reference : Authors Initials (Names) Surnames, *Book Title*, Publisher, Place of Publication, Page Range, Year of Publication.
- [2]. Article Reference : Authors Initials (Names) Surnames, Article Title, Journal Name, Volume Number, Serial Number, Page Range, Year.
- [3]. Website Reference : Authors Initials (Names) Surnames, Document Title, Date of Last Access.

Exercise 4.1 (Take Home Exercise) : A report entitled, “Didem Alkan Proje Raporu_Jammer_2013” can be downloaded from the course website, ece107.cankaya.edu.tr. Examine this report and make comments whether it conforms to the above outlined guidelines. For differences seen, comment on their usefulness.

These notes are based on

- 5) MATLAB m files.
- 6) My own Lecture Notes.