DIGITAL COMPASS, IS IT ERROR FREE?

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ملخص:

يعد قياس انحرافات الخطوط واحدا من المهام الرئيسية فى العمل المساحى، وفى غياب اجهزة الـــ GPS تعد البوصلة الوسيلة الوحيدة لتحديد الانحرافات. وقد ساعد تطور تكنولوجيا الدوائر المتكاملة فى تطوير الاجهزة المساحية وتحويلها الى اجهزة الكترونية، وقد شمل هذا التطور البوصلة التقليدية لتتحول الى بوصلة رقمية. وقد ساعدت الاجهزة الرقمية فى جعل العمل المساحى اكثر سهولة والقياسات المساحية اكثر دقة.
وفى هذا البحث تم دراسة البوصلة الرقمية للوقوف على دقتها فى تحديد الانحرافات ولمعرفة هل كونها رقمية يجعلها خالية من اهم عيوب البوصلة التقليدية وهو تأثرها بالجاذبية المحلية. ولتحقيق الغرض من البحث تم اجراء قياسات حقلية بالبوصلة الرقمية لانحرافات مجموعة من الأضلاع تم اختيارها في منطقة خالية من المؤثرات المغناطيسية الخارجية، كما تم قياس إحداثيات بداية ونهاية كل خط باستخدام أجهزة الـــ GPS لمعرفة الانحرافات الحقيقية للخطوط ثم أعيدت القياسات مرة اخرى بعد اضافة اجزاء حديدية الى مكان العمل كما تمت دراسة تأثر البوصلة بالمجال المغناطيسى الناتج عن التليفون المحمول. وقد تبين من مقارنة النتائج ان الانحرافات المقاسة من نفس النقطة لا تتأثر جميعها بنفس القدر من الخطأ الناتج عن الجاذبية المحلية مخالفة لما هو معروف فى البوصلة التقليدية.

ABSTRACT

Azimuth determination is one of the main tasks in the surveying work. The technology of Integrated Circuits (IC) helps in developing the most of the surveying instruments to be electronic ones. This development includes the traditional compass and a digital compass was produced. The digital instruments make the surveying work more easy and the measurements more accurate.
This paper concentrates on studying the accuracy of digital compass and its affected by the local attraction. To achieve this goal, field measurements were carried out by using GPS instrument and digital compass for several directions in an area free of magnetic interference and the measurements were repeated in presence of local attraction caused by steel rods and mobile phone. The results were compared and showed that as opposed to the traditional compass, not all directions measured from the same point had the same amount of error.

KEYWORDS: Digital compass; Magnetic bearing; Accuracy; Local attraction; GPS; mobile phone.

INTRODUCTION

Azimuth determination is one of the main tasks in the surveying work. The technology of Integrated Circuits (IC) helps in developing the most of the surveying instruments to be electronic ones. This development includes the traditional compass and a digital compass was produced. The digital instruments make the surveying work more easy and the measurements more accurate. The advantages of these devices are that they have no moving parts and are easy to interface with microprocessors and other types of navigation equipment. The wireless digital compass permits measurement of the linear and planar orientation of features, and improves upon the mechanical compass by automating the data collection process, facilitating the translation of orientation data to a geographical information system, and encouraging the collection of multiple measurements (Carr et al 2002). The surveyor's compass, like the Gunter's chain, has now become little more than a museum piece (Brinker and Wolf 1977).

(Kavanagh and Bird 2000) differentiate between azimuth and bearing. He defines the azimuth as the direction of a line given by an angle measured clockwise from the north end of a meridian, while he defines the bearing as the direction of a line given by the acute angle between the line and the meridian. In this paper, the word bearing instead of azimuth is the one used in the digital compass display.

This paper concentrates on studying the accuracy of digital compass and the effect of the local attraction. The local attraction is the magnetic attractions other than that of the earth's magnetic field (Moffitt and Bouchard 1987) which prevents the needle from pointing to the magnetic north in a given locality (Punmia B. C. 1978). To achieve this goal, field measurements were carried out by using both GPS and digital compass for several directions in an area free of magnetic interference and the measurements were repeated in presence of local attraction caused by steel rods and mobile phone.

THE DIGITAL COMPASS

Recently developed magnetic field sensors in integrated circuit (IC) technology have become available in low cost electronics packages. The advantages of these devices are that they have no moving parts and are easy to interface with microprocessors and other types of navigation equipment. The new IC magnetic field sensors use the magnetoresistive (MR) effect. MR sensors make use of an electrical current carrying magnetic material, which can change its resistance in the presence of an external magnetic field. The MR material used is called Permalloy and contains 19% Iron (Fe) and 81% Nickel (Ni). Using IC technology a thin Permalloy film is deposited on a nonmagnetic insulating substrate (chip) and 4 MR sensors are etched in the film in the form of a square, one sensor on each side. In electronics, this is called a bridge circuit. A bridge circuit is a very sensitive method to measure electrical resistance and changes in resistance. In some MR chip, two miniature electromagnets are also integrated on the IC to compensate and calibrate the MR sensors for magnetic field distortions caused by the metals found within automobiles, airplanes ships etc. The building blocks of an electronic compass consist of a two dimensional MR field sensor, a signal condition unit (SCU), a Direction Determination Unit (DDU) and a display. The MR sensors are placed in a plane 90 degrees from each other so that when one sensor is facing in a north - south direction it will have a maximum signal and the second sensor in an east-west direction will have a minimum signal. As the compass changes orientation the SCU amplifies the weak MR currents, compensates for temperature effects and delivers large signals to the DDU. The DDU derives the bearing information from the amplified MR sensor signals and determines the accuracy needed for the display. The display unit can provide simple 8 point compass headings (N, NE, E, SE etc.) and provide an alphanumeric display or light LEDs placed around a compass display. In more complex DDUs and displays, the compass heading can be displayed to 0.1 degree accuracy by using signal processing and computational corrections. In addition, the compass can display directions relative to magnetic north or true north at the users' location (mad sci network web site).

THE EARTH'S MAGNETIC FIELD

The earth's magnetic field (F) is composed of a vertical (Z) and horizontal (H) component. The magnetic field is perfectly vertical in the magnetic poles (horizontal intensity is zero) and perfectly horizontal in the magnetic equator (vertical intensity is zero). Everywhere else, there is a combination of vertical and horizontal components. The angle between the magnetic field and the horizontal component is known as Inclination (I) or magnetic dip angle. Declination (D) is the angle between true north and the horizontal trace of the magnetic field as shown in Figure (1). A good compass should point in the directions of the horizontal component of the magnetic field where the compass is located (Ojeda and Borenstein 2000).

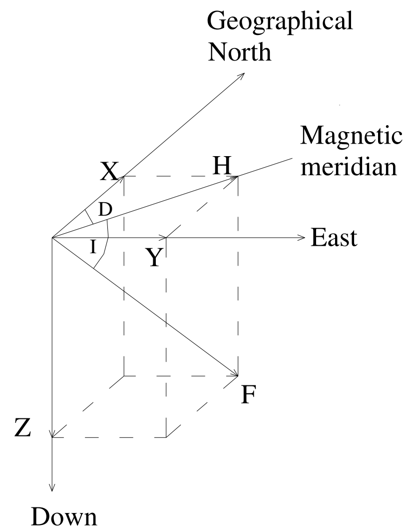

Figure (1): Magnetic-field components**:** Total Intensity (F)**,** Horizontal Intensity (H), Vertical Intensity (Z), North-South Intensity (X), East-West Intensity (Y), Inclination (I), Declination (D).[from U.S. Geological Survey].

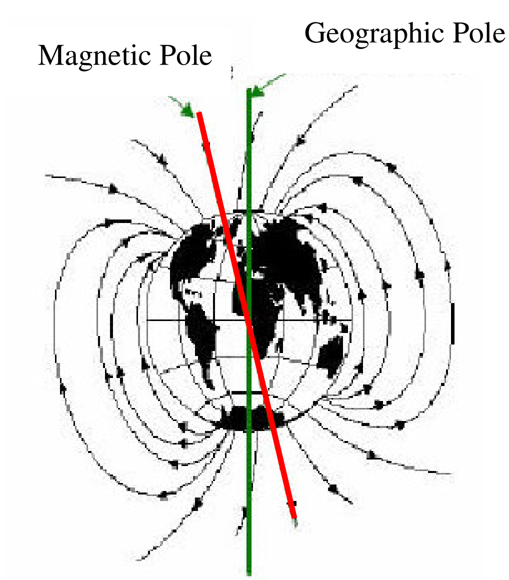

Figure 2**:** The earth's magnetic and geographic poles.

It is well known that the earth's magnetic poles do not correspond with its geographic poles as shown in Figure (2). Furthermore, the magnetic field is not perfectly uniform, it is irregular and it must be measured in many places to get a satisfactory picture of its distribution. This phenomenon is called Variation as shown in Figure (3). The variation is defined as the difference between the local magnetic meridian and the local geographic meridian at any particular point on the earth.

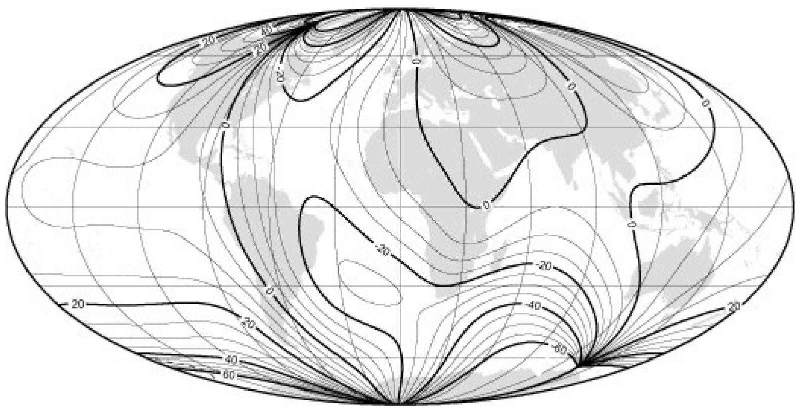

Figure 3: World variation model – 2000. (from U.S. Geological Survey)

COMPASS ERRORS

Compasses are vulnerable to distortion, because Earth's magnetic field is a weak signal (Hoff and Azuma 2000). Compass errors can be classified as absolute and relative errors, as shown in Figure (4)

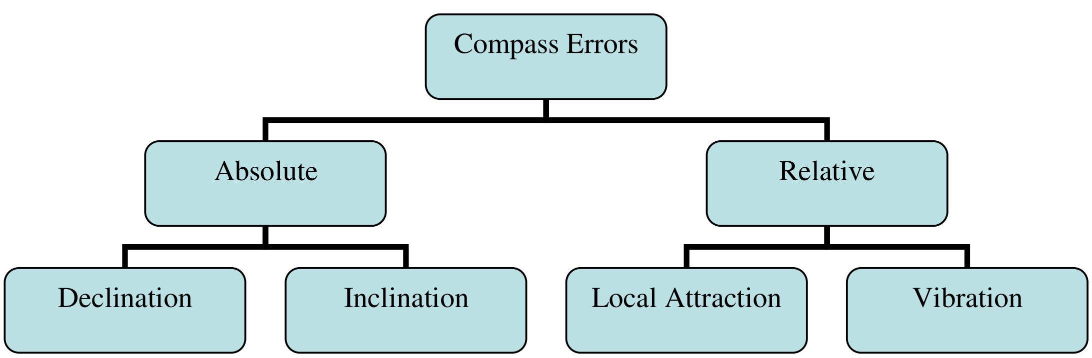

Figure 4: Compass errors.

Absolute error is defined as the difference between the compass reading and the geographic north direction on earth. The main factors that affect the magnitude of absolute error are declination and inclination.

The error caused by declination depending on the location (longitude and latitude) of the place where the compass is used as shown in Figure (3).

The inclination or magnetic dip angle could be a source of error, if the compass is not able to determine exactly the horizontal component of the magnetic field. Modern compasses as stated by (Ojeda and Borenstein 2000) use complex algorithms and techniques to reduce the effects of the magnetic dip angle. The two prevalent approaches for compensation are:

- to place the magnetic sensor in a fluid (gimbals) to ensure that the sensor element is always aligned with the horizontal component of the earth;
- to keep the magnetic sensor fixed and use an inclinometer (tilt sensor) to measure the inclination of the sensor with respect to the horizon of the earth, while the corrections are calculated using a compensation algorithm.

The sources of relative errors are the local attraction and the vibration.
Local attraction produces a deviation in the earth's magnetic field as shown in Figure (5), and, consequently erroneous readings in the compass. This interference might cause large errors and this research is a study of the effect of local attraction caused by steel rods and mobile phone on the compass readings.

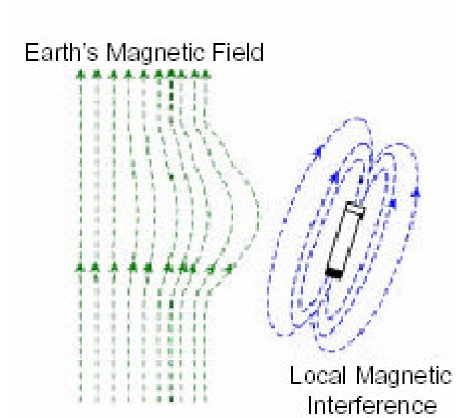

Figure 5: Deviation of earth's magnetic field by local attraction.

EXPERIMENTAL WORK AND RESULTS

The compass used in the experimental work is the KVH data scope that is a Fluxgate (FG) compass and rangefinder made by KVH. The Compass sensor is a two-axis fluxgate sensor. The compass can accommodate tilt angles of up to ±20°. It provides internal gimballing by floating the sensor coil in an inert fluid. The resolution of the compass is ±0.1°, with an advertised accuracy of ±0.5° (KVH web site). The characteristic responses of the MR compass and the FG compass are similar (NortekUSA web site).
To perform the experimental work a central point was chosen in a location that is free of known magnetic interference. Another eight points that make eight directions with the central points were marked. These directions are 0º (the magnetic north), 45º, 90º, 135º, 180º, 225º, 270º and 315º. Two GPS units were used to determine the coordinates of the end points of each direction and the true bearings were calculated. The compass was mounted on a purely wooden holder-has no magnetic interference- that was designed for this research to prevent the vibration. The compass was oriented so that it points to 0º (the magnetic north) and collect several readings. This step was repeated at each direction. The differences between the true and magnetic bearings are shown in Figure (6).

Several readings for the magnetic bearing of the direction of 45º (the direction that had the minimum difference between true and magnetic bearing) was collected again in presence of 12 surveying's steel rods each of 2.5 cm diameter, 210 cm length and 0.616 kg weight at distances 0.10, 0.25, 0.50, 1.0, 1.50 and 2.0 meter from the compass at each of the eight directions.
Figure (7) shows the relationship between the errors resultant in the bearing and the location of the local attraction for the different distances. The relationship between the error in the bearing and the farness of the local attraction from the compass for the different positions is shown in Figure (8). The results presented in these two figures show that the effective distance of that amount of local attraction is within 0.5 m from the compass and the maximum error occur when the local attraction was in the same direction that the compass was pointed or in a direction inclined of 270º from the measured direction. The error value was about ± 4º depending on the position of the local attraction from the compass sensor. The figures also show that a considerable error was resultant when the local attraction was 45º from each side of the measured direction. This result show clearly that not all directions that measured from the same point affected by the same amount of error.

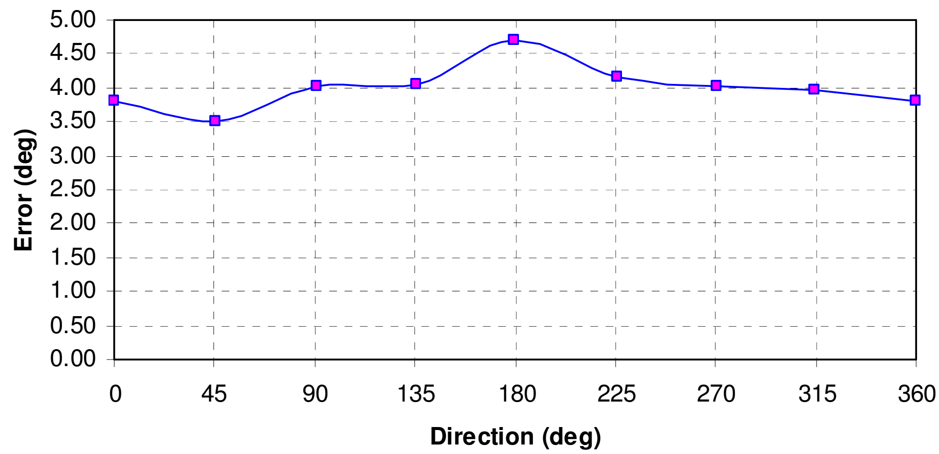

Figure (6): The differences between true and magnetic bearings.

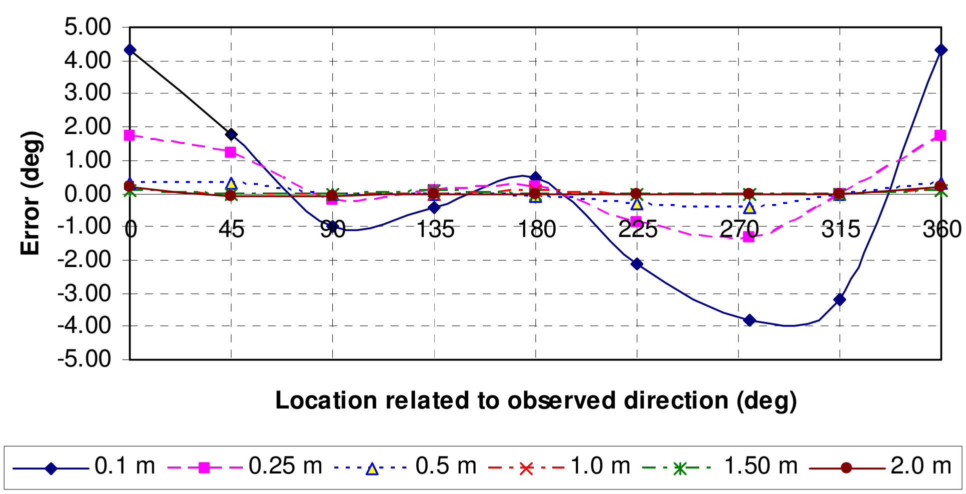

Figure (7): The relationship between the local attraction position and the error.

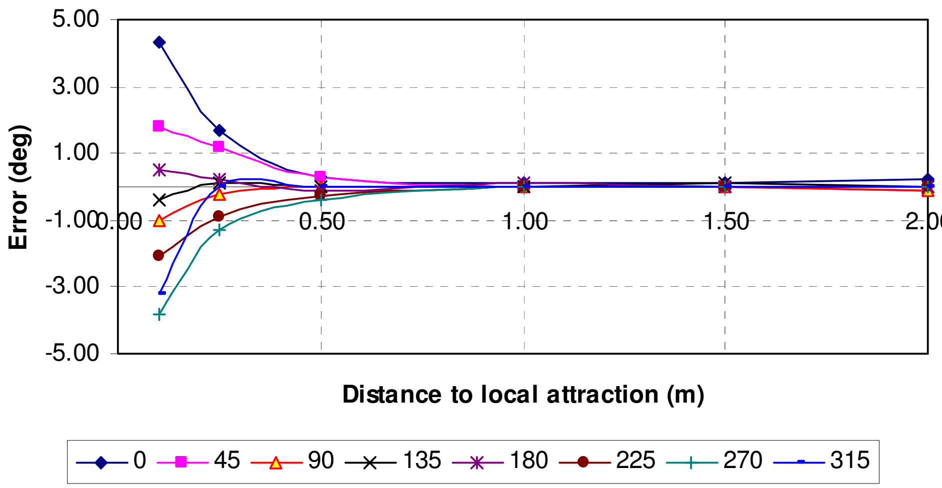

Figure (8): The relationship between the farness of local attraction and the error for the different locations.

To study the effect of the size of local attraction of the resultant error, the measurements were repeated with different sizes of the local attraction. The number of steel rods was reduced to be 6, 3 and 1 rod. Each time the steel rods are put at different distances and the bearing is measured. The steel rods are put once in the same direction of measuring and once again in a direction inclined by 270º from the measured direction (The positions that had the maximum error from the previous figures).

The results of the effect of the size when the steel rods are put in the same direction of measuring are shown in Figures (9) and (10). Figure (9) show the relationship between the error in the measured bearing and the number of steel rods for the different distances. From the figure its clear that the error increase with increasing the rod number specially when the local attraction was close to the compass.

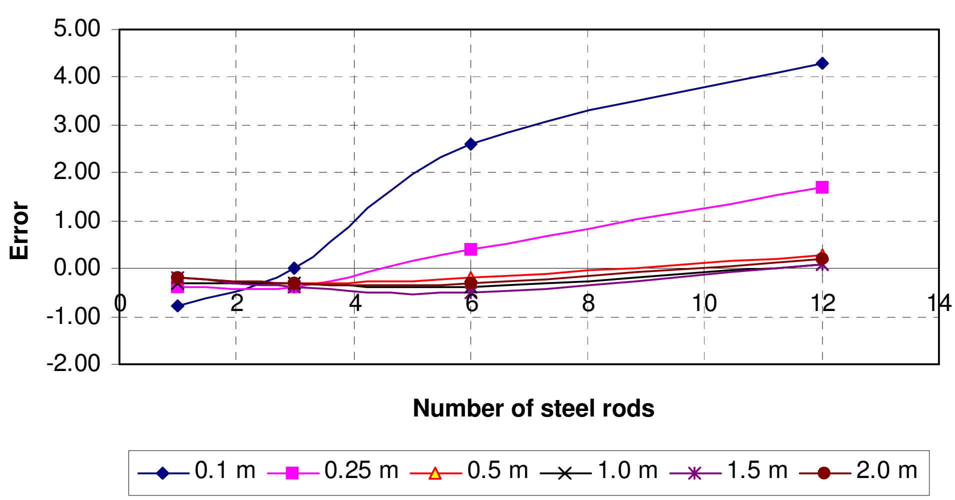

Figure (9): The relationship between the size of local attraction and the error.

The relationship between the errors and the farness of the local attraction for the different numbers are shown in Figure (10). The figure show that the effective distance increases with increasing the size of the local attraction (the number of steel rods). The same results were obtained when the rods were put in a direction inclined by 270º from the measured direction.

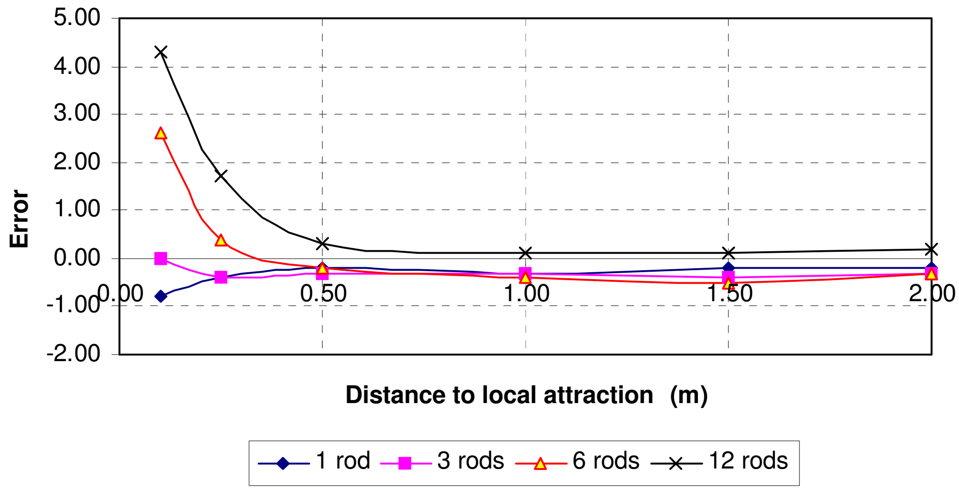

Figure (10): The relationship between the farness of local attraction and the error for the different sizes.

As the mobile phones become popular tool, its effect on the compass was studied. (Ripka and Billingsley 2000) stated that most of vector magnetic sensors are sensitive to magnetic fields perpendicular to their sensing direction. The mobile phone was put at different distances along the perpendicular to the measuring direction and the results show that it causes a big error in the compass reading specially when the part that contains the antenna was very close or adjacent to the compass sensor, as shown in Figure (11).

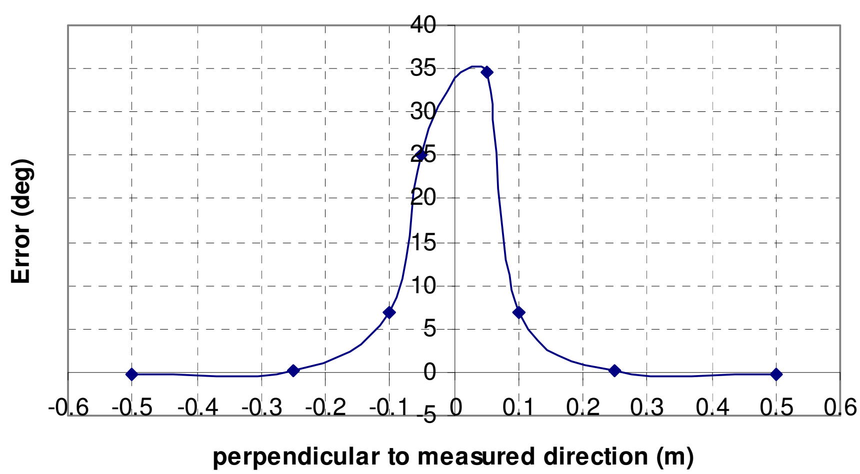

Figure (11): The error caused by mobile phone.

CONCLUSIONS

An examination of the digital compass was performed to study how it is affected by the local attraction. The experimental work showed that the digital compass is more accurate and easy to use than the prismatic one. The advantages of this device are that it has no moving parts and is easy to interface with microprocessors and other types of navigation equipment. From the results, the following remarks can be concluded:

- The position (both distance and direction) of the local attraction has a great effect on the measured bearing.
- Not all direction measured from the same point had the same amount of error.
- The most effective position of the local attraction is when it was in the same direction of measuring or inclined by 270º from it.
- The error in the measured bearing is proportional to the local attraction size and inversely proportional to the distance.
- The mobile phone has a great effect on the compass reading and it causes a big error (up to 35º) when it was very close or adjacent to the compass sensor. This error decreases rapidly till it reaches zero at a distance about 25 cm.

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