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# Radio Technology Frequency Identification Applied in High-Voltage Power Transmission-Line for Sag Measurement

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***Abstract*****—**High-voltage power transmission lines are the back bone of electrical power utilities. The stability and continuous monitoring of this critical infrastructure is pivotal. Nine-Sigma representing Eskom Holding SOC limited, South Africa has a major problem on proactive detection of fallen power lines and real time sagging measurement together with slipping of such conductors. The main objective of this research is to innovate RFID technology to solve this challenge. Various options and technologies such as GPS, PLC, image processing, MR sensors and etc., have been reviewed and draw backs were made. The potential of RFID to give precision measurement will be observed and presented. The future research will look at magnetic and electrical interference as well as corona effect on the technology.

***Keywords*****—**Precision Measurement, RFID and Sag.

## I. Introduction

LONG distance high voltage power lines are very important in electricity power delivery because power stations are normally built far away from power loads. During the transmission process, balance must be constantly maintained to match the power supply and demand. World climatic changes have an impact on our existing electrical transmission line performance. The electric current flowing in the lines should be measured to avoid overloads, phase unbalance and fluctuation. Line positions should be monitored to keep track of the sagging and galloping situations. Sagging can lower the conductor to a usage height above the earth. The oscillations can cause serious transmission problems, such as flashover due to infringed line to line clearance, risk of mechanical failure of transmission tower, and excessive loading stress [3], [7].

Current transformers (CTs) are typically used for current measurement. However, they are expensive and limited by their magnetic core characteristic and narrow bandwidth [1]. There are some existing devices that can directly or indirectly measure sag of transmission lines.

Power line Carrier method (PLC), determines average overhead conductor height variations by correlating sag with measured variations in the amplitude of signals propagating between PLC stations [8], [9]. This is not accurate as conductors swing differently in different conditions.

Power donut is a temperature sensor platform installed on live wires [2]. However, this device measures the conductor surface temperature rather than the core temperature for calculating sag. In addition, it is an expensive platform and its installation requires working with live wires.

Application of the global positioning system (GPS), based on a constellation of 24 satellites, which uses the Navigation satellite Timing and Ranging (NAVSTAR) developed, launched, and maintained by the United States government [4]. This method relies on accurate time-pulsed radio signals in the order of nanoseconds from high altitude Earth orbiting satellites of about 11 000 nautical miles, with the satellites acting as precise reference points. This technique is promising; however the challenge such as electromagnetic interference (EMI) from the phase conductors is questionable.

Machine vision and Image processing based on camera [5]. It is a costly technique and its installation requires contact with phase conductors for placing the targets.

Electromagnetic Coupling Method is based on the magnetic field surrounding the conductor [7]. For different line configurations, the grounded wire position and the sag calculation need to be modified. Also, Electro Magnetic Interference from nearby transmission lines cannot be neglected.

Magneto resistive *(MR) sensors* were recently applied for sag measurement. It calculates the current flow and line positions from the magnetic field emanated from the phase conductors [6]. Provided the sensitivity of the magnetic sensors is sufficient, the electric and spatial information of the overhead line can be found by inverse calculation from the magnetic field measured at the ground level. However the accuracy of this technique is questionable. Factors such as multiple power conductors, bundle conductors and image current due to a conducting ground have to be taken in to consideration.

Autonomous robot technique uses energy from the line and run along the conductor while making the inspection [10]. The stability and reliability of this technique is questionable as the magnetic field emanated from the conductors always vary and the storage of such.

A novel application of Radio Frequency Identification Technology (RFID) which is proposed in this paper has the potential to address the drawbacks of the other methods. It has

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a potential to calculate the sag in real time with signals travelling at the speed of light identifying the transponder attached on the conductor. Figure below illustrates the sag on a single span, where sag (y) = total height (H) – height (h).

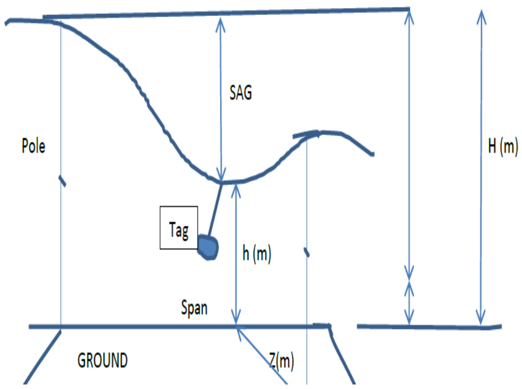


Fig. 1 Illustration of a sagged conductor

## II. RFID Technology

### A. Background

RFID has been around since World War II, where it was used to help solders identify fighter planes. It provides a mean of storing data and retrieving data through electromagnetic wave transmission to an RFID compatible integrated circuit.

The operation of RFID is based on the basic theory of electromagnetic field given [11].

$$\nabla . B = 0, \quad (1)$$
$$\nabla . D = 4\pi\rho, \quad (2)$$
$$\nabla \times H = (4\pi / c) j + 1 / c \partial D / \partial t, \quad (3)$$
$$\nabla \times E = -1 / c \partial B / \partial t, \quad (4)$$

where D is the electric (displacement) field, E is the electric field; B is the magnetic (induction) field, H is the magnetic field, j is the conduction current density vector field, p is the charge density, and $\nabla$ is the usual differential operator. This theory generates the platform for a RFID system. The system is made up of transponders normally known as tags which are divided in to two categories namely, passive and battery aided. The tags are assumed to be suspended to the power line to be identified and the reader to the computer network which process the data.

Passive RFID transponders operate on radiated energy from the reader, while battery aided transponders get energy from their own source. Passive transponder comprise of a single integrated circuit mounted on a simple antenna.

### B. Energy Transfer Topology

Passive transponders use energy transferred from the reader via the antennas to power up their circuits. Energy propagates through the air and through conductors in the form of a combination of magnetic and electric signal. The electric components of the signals are much more effective in travelling through air over longer distances than magnetic signals. However antennas for electric signals have a size issue, as in order for them to be very efficient, they need to be approximately half the wavelength of the operating frequency in physical dimension. This means that at frequencies below 100Hz, the antennas for electric propagation mode are physically too large to be practical for the application of RFID. At UHF RFID of 860MHz to 960MHz the antennas still have dimensions in the order of 160millimetres. This physical size restriction means that at frequencies below 100MHz, magnetic propagation modes are used while above 100MHz electric fields are used.

### C. Energy Field Propagation

Magnetic coupled transponders use the operating frequency of 125 KHz and 13.56 MHz.

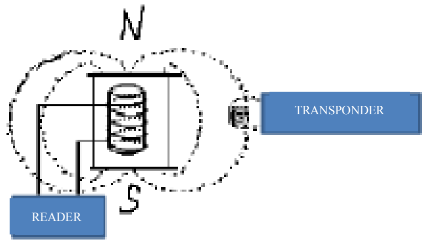


Fig. 2 The energy field propagation using magnetic field

The read range of such transponders is about 20millimetres, meaning that they are suitable for identifying items when the reader is almost in contact with the transponder. As the transponders are small and use magnetic fields, they can be placed inside a body or even a lump of metal, as long as they can be orientated along the lines of flux. Such transponders are used in car keys for ignitions, asset identification and etc. Since 1998 a new series of magnetic coupled tags has been available which operates at 13.56MHz, requiring a fewer turns than the 125 kHz transponder antenna and hence cheaper to manufacture.

Electric field passive tags operate in the 860 to 960MHz bands and at 2.45GHz. Electric field energy radiates from the source at the speed of light, spreading this energy in all directions.

Every doubling of distance spreads the energy over four times the area reducing the energy density available. The wavelength of the radio wave is equal to the speed of light divided by the operating frequency.

At 100 MHz, the wavelength is 3 meters; while at 915MHz is 0.32 meters and 0.12 meters at 2.45GHz. It is clear that the efficiency of the antenna depends on its dimensions and its operating frequency. The important criterion is the capturing area of the antenna, known as antenna aperture, which represents the area on the sphere of radius equal to the distance from the source, where the energy passing through that area is converted to power for the transponder to use. The aperture is proportional to the square of the wavelength meaning that at higher frequencies the aperture becomes very small. Table I below show the summery of the Electric Field antenna performance.

TABLE I
ELECTRIC FIELD ANTENNA PERFOMANCE

| Antenna Dipole | Aperture Area | Operating Frequency | Wavelength |
|---|---|---|---|
| 868MHz | 149 $cm^2$ | 100MHz | 3m |
| 915MHz | 133 $cm^2$ | 915MHz | 0.32m |
| 2.45GHz | 18 $cm^2$ | 2.45GHz | 0.12m |

Fig. 3, below depicts the Antenna aperture where electric field radiates from the source at speed of light. Every doubling of distance spreads the energy over four times the area reducing the energy density available.

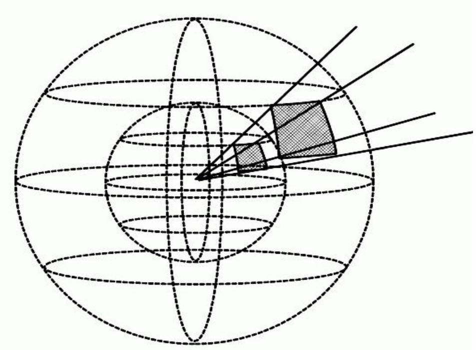

Fig. 3 Antenna aperture

It is observed that due to the reduction of aperture, the passive transponders cannot operate at frequency higher than 2.45GHz. Only battery aided transponders could operate above this frequency. It can be concluded that from 860MHz to 960MHz frequency band could be best suitable the operating range, low power transmission and antenna size for passive RFID.

*D. Master Plan of Radio Spectrum*

Based on performance and specific usage, there are five different frequencies allocated in individual countries.

TABLE II
DIFFERENT FREQUENCIES ALLOCATED FOR INDIVIDUAL USE

| Frequency | RFID Application | Transponder to be used |
|---|---|---|
| 125kHz (Magnetic mode) | Access control such as car immobilizer | Passive = Low frequency |
| 13.56MHz (Magnetic mode) | Smartcard such as credit card | Passive = High frequency |
| 900MHz (Electric Mode) | Asset tracking such as identifying goods location | Passive = Ultra High frequency |
| 2.45GHz (Electric mode) | Electronic toll gate collection using RADAR | Battery Aided = Micro wave |
| 5.8GHz (Electric mode) | Long range Precision Measurements using RADAR | Battery Aided = Micro wave |

*E. RFID Radar System Architecture*

The architect of RFID is made up of reader circuit, antenna and a tag. Fig. 4 shows a simple circuit of antenna and tag.

A conventional dipole type antenna has a power circuit as shown in Fig. 4. The impedance is 72ohms. The energy collected in the aperture of the dipole is converted to an AC voltage which is then doubled and peak detected to give a voltage on the capacitor that can be used to power up the transponder circuit.

TABLE III
RFID ARCHITECHER OPERATING VOLTAGE

| Antenna Voltage | Tag Voltage | RF Power |
|---|---|---|
| 5Volts | 2Volts | 54mW |
| 3Volts | 1.3Volts | 23mW |
| 0V – 2V (RFID-radar) Eco tag | 0V – 1V | 0.2mW |

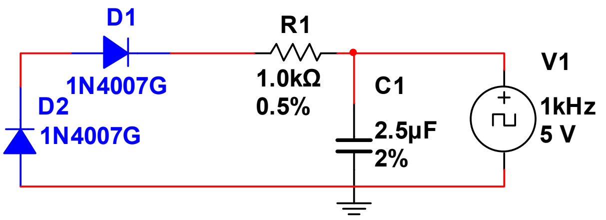


Fig. 4 Power circuit of a dipole type antenna

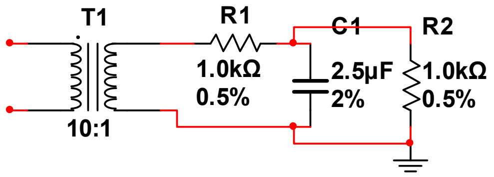


Fig. 5 Main parts of RFID tag

The main parts of RFID tag show on Fig. 5 include the rectifier made of diodes, which rectifies input RF signal and generate the DC voltage the other components or blocks of the system.

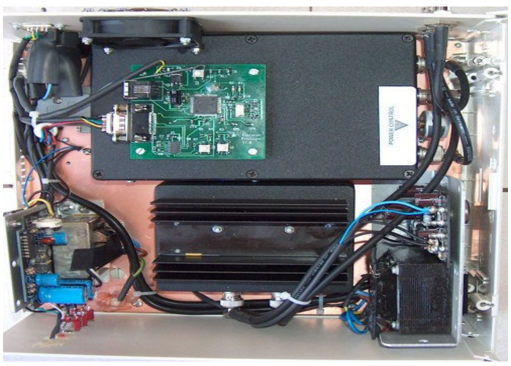

Fig. 6 RFID Radar (reader) circuit board

The RFID reader (radar) makes two measurements on each signal received from each transponder in its receiving zone; which is range and angle of arrival. It has the ability to measure range with narrow bandwidth with the same transponders that are used by conventional RFID readers. The system uses 10 KHz of bandwidth to operate, which give it the ability to detect time differences only as small as 0.1 milliseconds, of 0.0001 seconds. In this particular time the radio wave will travel 30KM while the radar is determining the range of the transponder based on its received transmission to an accuracy of a few centimeters better than its normal time measuring properties.

In conventional RFID military radar approach, we have to measure the time of flight to 0.3pico seconds to get a centimeter precision, which would use 300GHz of the radio spectrum.

## III. Measurements and Tests

Relative range stability of BCBBB0026 Transponder was used and observed at about 36m

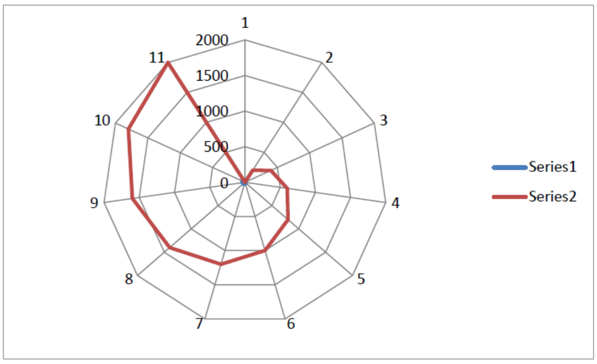


Fig. 7 Variation in millimeters

Series 1 refer to the variation in millimeters and series 2 shows number of readings at each bin over the 1 hour test. Readings were noted at one second intervals.

### A. Accuracy Test Results

Different types of transponders were used and the table below reports each identity number with its range. There were 3 tag sticks which are shown in the range meter radar graph.

TABLE IV
Identity Tag Range

| Tag Identity | Type | Range(m) |
|---|---|---|
| BBBFK0898 | Credit card passive | 14.3 |
| BCBBB5026 | Claymore | 36 |
| BCBBB0003 | Stick tag with reflector | 37.950 |
| BCBBB0002 | Stick tag | 9.1 |
| BCBBB0026 | Clay more | 36.15 |
| BCBBB5025 | Clay more | 19.3 |
| BCBBB0004 | Stick tag with reflector | 35.40 |

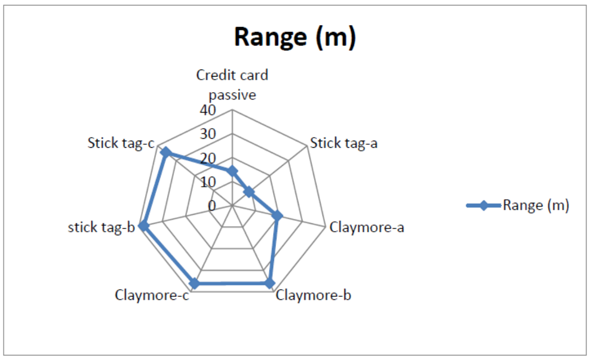


Fig. 8 RFID tag identification

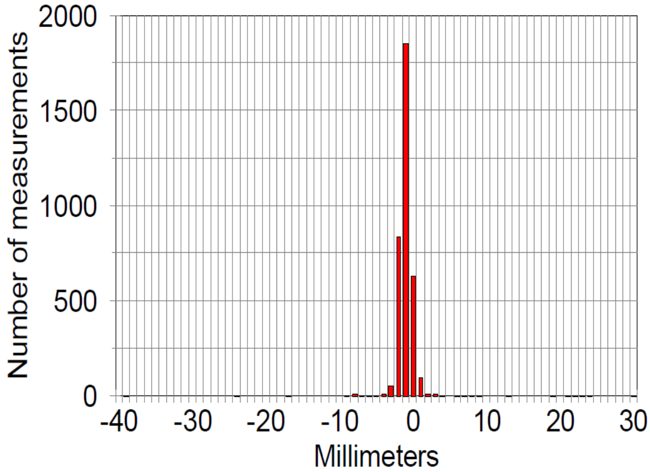


Fig. 9 RFID radar relative range stability of BCBB0002 at 9m

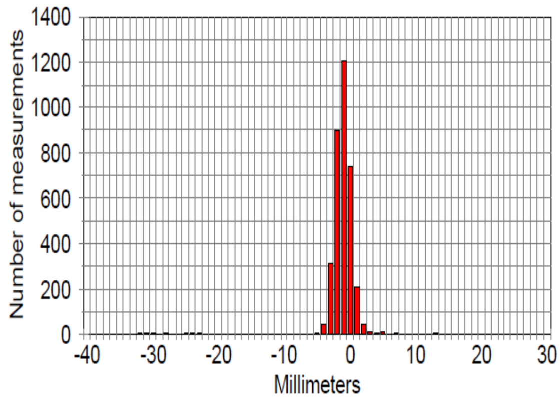


Fig. 10 RFID radar relative stability of BCBBB0026 for approximately 36m

## IV. Conclusion

RFID technology has the potential to carry the long range precision measurement. Compared to the military wide bandwidth type, RFID radar uses little bandwidth which allow it not to interfere with other communication systems. The angle of arrival measurement is virtually instantaneous and used in conjunction with range and gives a 2D positioning system from a single measuring location. Non-thermal plasma which occurs in close vicinity to a thin discharge electrode, such as a pin or a wire at a high potential is known as corona. This phenomenon is very complex to deal with in high voltage Power transmission. Our future research will examine the extend which this can have an effect on the RFID transponder.

## References

[1] A. Cataliotti et al., "Characterization of current transformers in the presence of harmonic distortion, Presented at the" IEEE Int. Instrum. Meas. Technol. Conf., Victoria, Vancouver Island, Canada, 2008.
[2] L. Fish, Low Cost Sensors for Real Time Monitoring of Overhead Transmission Lines. Washington, DC: Underground Systems Inc., 2006.
[3] February 5, 2010, Tension Monitor [online], available online http://www.cat-1.com).
[4] G. Thomas Heydt, fellow, IEEE, "Application of the Global Positioning System to the Measurement of overhead Power Transmission Conductor Sag," IEEE Trans. Power Del., Vol. 17 NO. 1, pp 273-278, January 2002.
[5] R.G. Olsen and K.S. Edward, "A new method for real-time monitoring of high-voltage transmission-line conductor sag," IEEE Trans, Power Del., vol.17 no.4 pp. 1142-1152, Oct. 2002.
[6] C Mensah-Bonsu, "Novel application of Magnetoresisteve Sensors for High-Voltage Transmission-Line Monitoring," IEEE on Magnetics, Vol. 47 NO. 10 October 2011.
[7] S.W. Rienstra, "Nonlinear free vibration of coupled ns. Power Delivery, vol. PWRD-2, pp. 851-856, July 1987. spans of overhead transmission lines," in proc. 3rd Eur. Conf. Math. Ind., 1988 pp 133-134.
[8] R. G. Olsen and K.S. Edwards, "A new method for real-time monitoring of high voltage transmission line conductor sag," IEEE Trans. Power Del., vol.17, no. 4 pp 1142 – 1152, Oct. 2002.
[9] Wernich de Villiers, and Arthur Burger, "Real-time sag monitoring system for high voltage transmission lines based on power-line carrier signal behavious" IEEE Trans. On power del., Vol.23, NO.1, January 2008.
[10] Xignlong Zhu, and Jiping Shou, "An Autonomous Obstacles Negotiating Inspection Robot for Extra-High Voltage Power Transmission lines".
[11] Graham Hall "maxwell's electromagnetic theory and special relativity" Phil. Trans. R. Soc. A 2008, published 28 May 2008.