International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 3 (2018) pp. 1664-1669
© Research India Publications. http://www.ripublication.com

Analysis and Study the Performance of Coaxial Cable Passed On Different Dielectrics

Baydaa Hadi Saoudi

Nursing Department, Technical Institute of Samawa, Iraq.
Email:baydaa_s2007@yahoo.com

Abstract

In this research will discuss the more effective parameter is the type of dielectric mediums (Polyimide, Polyethylene, and Teflon).

This analysis of the performance related to dielectric mediums with respect to: Dielectric losses and its effect upon cable properties, dielectrics versus characteristic impedance, and the attenuation in the coaxial line for different dielectrics. The analysis depends on a simple mathematical model for coaxial cables to test the influence of the insulators (Dielectrics) performance. The simulation of this work is done using Matlab/Simulink and presents the results according to the construction of the coaxial cable with its physical properties, the types of losses in both the cable and the dielectric, and the role of dielectric in the propagation of electromagnetic waves. Satisfied results are obtained that concluded the condition of high performance for coaxial cable.

INTRODUCTION

The coaxial cable has an inner conductor surrounded by a tubular insulating layer, surrounded by a tubular conducting shield. Many coaxial cables also have an insulating outer sheath or jacket. The term coaxial comes from the inner conductor and the outer shield sharing a geometric axis as shown in fig. 1. Historically, in 1880 an English mathematician Oliver Heaviside studied the so-called skin effect in telegraph transmission lines. He concluded that wrapping an insular casing around a transmission line both increases the clarity of the signal and improves the durability of the cable. He patented the first coaxial cable in England after that year. Four years afterwards (in 1884), the first Coaxial cable was made by an electrical engineering company named Siemens [1-3].

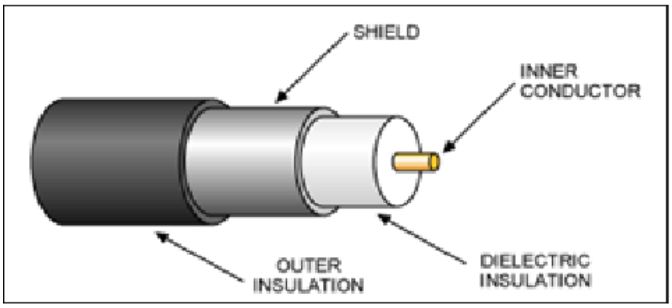

Figure 1: The cross section of coaxial cable

Coaxial cable virtually keeps all the electromagnetic wave to the area inside it. Due to the mechanical properties, the coaxial cable can be bent or twisted, also it can be strapped to conductive supports without inducing unwanted currents in the cable. The speed(S) of electromagnetic waves propagating through a dielectric medium is given by:

$$S= c/ (\mu r\ \varepsilon r)\ \hat{}\ ½.$$

C: the velocity of light in a vacuum

μr: Magnetic relative permeability of dielectric medium

εr: Dielectric relative permittivity.

The most common dielectric material is polyethylene, it has good electrical properties, and it is cheap and flexible. Therefore, it is a material of choice for insulation of coax cable. Polyethylene has lower dielectric losses than PVC and is sensitive to moisture under voltage stress (i.e. for high voltages only).

BASICS OF COAXIAL CABLE

Coaxial feeder is normally seen as a thick electrical cable. The cable is made from a number of different elements that when together enable the coax cable to carry the radio frequency signals with a low level of loss from one location to another.

The overall construction of the coax cable or RF cable can be seen in the diagram below and from this it can be seen that it is built up from a number of concentric layers. Although there are many varieties of coax cable, the basic overall construction remains the same:

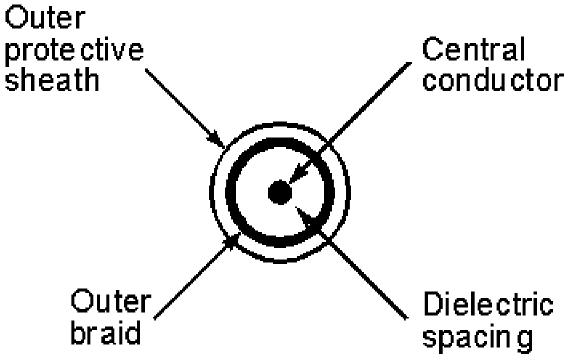

Figure 2: Cross section though coaxial cable

1. **Centre conductor**: The center conductor of the coax is almost universally made of copper. Sometimes it may be a single conductor whilst in other RF cables it may consist of several strands.
2. **Insulating dielectric**: Between the two conductors of the coax cable there is an insulating dielectric. This holds the two conductors apart and in an ideal world would not introduce any loss, although it is one of the chief causes of loss in reality.
3. **Outer conductor** The outer conductor of the RF cable is normally made from a copper braid. This enables the coax cable to be flexible which would not be the case if the outer conductor was solid.
4. **Outer protecting jacket or sheath**: Finally there is a final cover or outer sheath to the coax cable. This serves little electrical function, but can prevent earth loops forming. It also gives a vital protection needed to prevent dirt and moisture attacking the cable, and prevent the coax cable from being damaged by other mechanical means.

COAXIAL CABLE APPLICATIONS

One of the broadest uses of coaxial cable is for video distribution. From CATV signals around the neighborhood to precision digital signals in a post-production studio, these signals are routed on 75 ohm coaxial cable. Broadband CATV (or MATV) signals typically use a series 59 (RG-59) or series 6 (RG-6) type coaxial cable, or drop cable. These cables use copper covered steel conductors and aluminum foil/braid combination shields (outer conductors). They are designed for use above 50 MHz, with high strength, low weight and low cost the primary factors.

DESIGN ADVANTAGES OF COAXIAL CABLE

The center conductor, dielectric, shield and sheath are constant throughout the production process, controlled to give a precise, constant spacing between the inner and outer conductor, as a result the variation of impedance “impedance tolerance” is very small. Even normal installation conditions such as being bent, flexed or stepped on have little effect on the performance of a good quality coax.

METHODOLOGY

EQUIVALENT CIRCUIT OF THE COAXIAL CABLE

Generally, like any transmission line, the coaxial cable has these four parameters; capacitance, resistance, conductance and inductance [8-9]. The equivalent circuit of a coaxial cable shown in fig. 3:

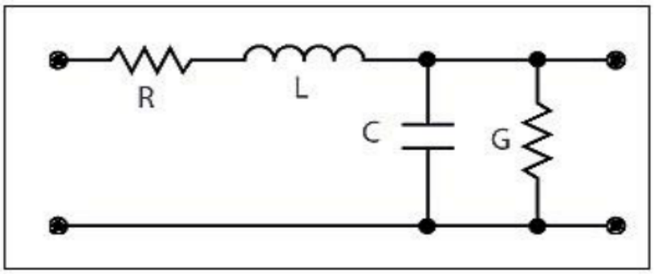

Figure 3: The electrical model of coaxial transmission line

In this research, the examination of how the electrical performance of a coaxial cable has made, notably loss and distributed capacitance/inductance can affect the integrity of a signal and the differences of dielectrics can change those values and finally the performance of the cable. The coaxial cable circuit contains:

- **Shunt capacitance:**It is the capability of the coaxial to carry a charge. It is measured per unit length (Farad per meter).

$C=2\pi\epsilon/\ln(D/d)$ ………………………………….(1)

Series resistance: ohms per meter. The resistance per unit length is just the resistance of the inner conductor and the shield at low frequencies. At higher frequencies, skin effect increases the effective resistance by confining the conduction to a thin layer of each conductor.

Dielectric loss is caused when the insulating material inside the transmission line absorbs energy from the alternating electric field and causes a high heat.

$R=(1/2\pi)*((1/d)+(1/D))*(\pi f\mu/\sigma)^{0.5}$ ……………………..(2)

- **Shunt conductance:**

Generally in coaxial cables, the shunt conductance is very small because dielectrics with good properties are used (low dielectric constant). At high frequencies, a dielectric can have a significant resistive loss.

$G=2\pi\sigma/\ln(D/d)$………………………….. (3)

- **Series inductance:**

to represent or simulate the magnetic field around the wires, self-inductance is represented by a series inductor (Henries per unit length) it is given by

$L=(\mu/2\pi)*\ln(D/d)$ ………………….(4)

- **Characteristic impedance:**

This is the total opposition or resistance to the flow of electrical energy within the cable. It is a complex value defined by the cable’s resistance, capacitance, inductance, and conductance, and is the equivalent value of these items combined.

$Z=((R+jL)/(G+jC))^{0.5}$………………… (5)

Where, d: Outside diameter of inner conductor

D: Inside diameter of the shield

μ: Magnetic permeability of dielectric medium

ϵ: Dielectric permittivity of the dielectric medium

σ: Conductivity of the inner conductor

COAXIAL CABLE ATTENUATION

The power loss caused by a coax cable is referred to as attenuation. It is defined in terms of decibels per unit length, and at a given frequency. Obviously the longer the coax cable, the greater the loss, but it is also found that the loss is frequency dependent, broadly rising with frequency, although the actual level of loss is not linearly dependent upon the frequency.

For virtually all applications the minimum level of loss is required. The power is lost in a variety of ways:

Resistive loss: Resistive losses within the coax cable arise from the resistance of the conductors and the current flowing in the conductors results in heat being dissipated. The actual area through which the current flows in the conductor is limited by the skin effect, which becomes progressively more apparent as the frequency rises. To help overcome this multi-stranded conductors are often used.

Dielectric loss: The dielectric loss represents another of the major losses arising in most coax cables. Again the power lost as dielectric loss is dissipated as heat. It is found that the dielectric loss is independent of the size of the RF cable, but it does increase linearly with frequency

Radiated loss: The radiated loss of a coax cable is normally much less than the resistive and dielectric losses. However some very cheap coax cables may have a very poor outer braid and in these cases it may represent a noticeable element of the loss.

Coax Cable Attenuation With Time

Although many coax cables are flexible, the level of loss or attenuation will increase, particularly if the RF cable is bent sharply, even if within the makers recommended bend radius. This increase in loss can arise as a result of disruption to the braid or screen, and as a result of changes to the dielectric. At frequencies of 1 GHz with RF cables normally exhibiting a loss of 10 dB, there could be an increase of a decibel or so.

COAXIAL CABLE SPECIFICATIONS & PARAMETERS

In order to understand the performance of the coaxial cable it is necessary to understand the specifications for the different parameters.

Characteristic impedance specification

Possibly one of the most defining coax cable specifications is its characteristic impedance. This is the impedance seen looking into an infinitely long length of cable by a signal source. The dimensions of the cable along with the dielectric used determine the overall impedance. This specification is measured in ohms and is resistive.

The most common impedance figures are:

- **50/52 ohms** : This cable is the form that is generally used for professional RF applications.
- **75 ohms:** This impedance is more widely used in domestic applications for television and hi-fi RF signal leads.
- **93 ohms:** Coax with this impedance specification was used in many early computers, linking the computers themselves and also monitors. It was used because of its low capacitance level.

Loss / Attenuation Specification

Another major parameter for coaxial cable is its loss or attenuation. It is found that there is a degree of loss as a signal travels along a coax cable. This arises from a number of factors and is present on all cables. It is also proportional to the length.

The coax loss or attenuation parameter is specified in terms of a loss over a given length. It is generally specified in terms of a loss measured in decibels over a given length, e.g. 0.5dB / 10 meters.

Power rating specification

Although for low level signal applications the power rating is unlikely to be important, where higher power levels are being carried, this specification can be an issue. Normally the limiting factor arises from the heat loss within the cable. If the power in the RF cable is to be pulsed, then it is necessary to check that the operating voltage is not exceeded.

Velocity factor specification

The velocity factor specifications of a coaxial cable is the speed at which the signal travels within the cable compared to the speed of the signal (i.e. speed of light) in a vacuum. It is found that cables have very similar velocity factor figures. This is because the dielectric between the two conductors governs the velocity factor. Cables using a solid polyethylene dielectric will have a velocity factor around 0.66, and that using foam polyethylene will have velocity factor figures ranging from about 0.80 to 0.88.

Capacitance specification

For some applications the capacitance specification of the coax cable will be important. As can be imagined, there is a capacitance between the inner and outer conductors of the cable, and this is proportional to the length of cable used as well as the dielectric constant and the inner and outer conductor diameters.

Maximum voltage

In some applications the voltage may rise to high levels. At some voltage it is possible the cable may break down, causing damage to the cable itself.

Voltages can arise as a result of high levels of standing waves and high power levels. Checks should be made, before selecting a particular type of coax, that it will be able to withstand the level of voltage anticipated.

Coax mechanical dimensions specification

The mechanical dimensions specification of the coax is important for a variety of reasons. The dimensions of different coax cables are obviously often different. Larger diameter coax cables often tend to have lower loss levels and higher power ratings.

COAXIAL CABLE ENVIRONMENTAL RESISTANCE

There are many factors that affect coax cables to greater or lesser degrees:

Effect of humidity and water vapour on coax cables

One of the biggest enemies for coaxial cable is that of water vapour. If it enters a coax cable then it can significantly degrade its performance, requiring the cable to be replaced. Moisture causes two main effects that give rise to an increase in the level of attenuation or loss in the cable. The first is an increase in resistive loss arising from oxidation of the braid that gives rise to an increase in the resistance of the braid or outer conductor in the coax cable. The second is an increase in the loss arising in the dielectric.

Effect of sunlight on coax cables

Sunlight has an effect on many substances, and the same is true of coax cable jackets or sheaths. It is particularly the ultra-violet light that causes the degradation to the cables. To increase the life of coax cables, manufacturers use high molecular weight polythene. Polyvinylchloride (PVC) jackets exhibit less than half the life expectancy of the high molecular weight polythene.

Effect of corrosive vapours on coax cables

Using a coax cable in the vicinity of corrosive liquids and vapours can reduce the life of a cable faster than if it was used externally. Salt water is a common problem on sea going vessels, and chemical vapours may be present on other installations requiring coax cables.

PRACTICAL RESULTS

PRACTICAL MODEL OF COAXIAL CABLE

The coaxial transmission line with many different dielectrics has been tested in Matlab to show the effect of the different dielectric in the coaxial cable. By applying all the equation in the theoretical calculation in the Matlab code to test the performance of the dielectric and display it in the tables (1-5). The Air has been tested as a dielectric, and it has good performance, but because of mechanical limitations it cannot be practically used. Every dielectric has different properties which mean different attenuation constant.

Table 1. Relative Permittivity of the Tested Dielectrics

	Dielectric	εr
1	Polyimide	3.4
2	Polyethylene	2.25
3	Teflon	2.1

The specifications are:

•6 MHz propagation wav

•Outside diameter of inner conductor (d= 0.45)

•Inside diameter of the shield (D = 1.47)

•Conductor conductivity = 5.8e7

•Propagation constant equation (γ)

$$\gamma = ((R+JwL)(G+JwC))^{0.5}$$

TABLE 2
MATLAB RESULTSOF AIR AS A DIELECTRIC

	Coaxial Parameters	Air (εr = 1)
1	Shunt conductance (S/m)	5.3078e-16
2	Shunt capacitance (F/m)	4.6931e-11
3	Series inductance (H/m)	2.3675e-07
4	Series resistance (ohm/m)	9.3354
5	Gamma	0.0657+125.664i
6	Alpha α (Np/m)	0.065718
7	Beta β (rad /m)	25.6637
8	Characteristic impedance (ohms)	71.026-0.03714i

TABLE 3
MATLAB RESULT OF POLYIMIDE AS A DIELECTRIC

	Coaxial parameters	Polyimide(εr = 3.4)
1	Shunt conductance (S/m)	5.3078e-16
2	Shunt capacitance (F/m)	1.5957e-10
3	Series inductance (H/m)	2.3675e-07
4	Series resistance (ohm/m)	9.3354
5	Gamma	0.1212+231.71i
6	Alpha α (Np/m)	0.12118
7	Beta β (rad /m)	231.7125
8	Characteristic impedance (ohms)	38.52-0.0201i

TABLE 4
MATLAB RESULT OF POLYETHYLENE AS A DIELECTRIC

	Coaxial parameters	Polyethylene (εr=2.25)
1	Shunt conductance (S/m)	5.3078e-16
2	Shunt capacitance (F/m)	1.0559e-10
3	Series inductance (H/m)	2.3675e-07
4	Series resistance (ohm/m)	9.3354
5	Gamma	0.0986+188.495i
6	Alpha α (Np/m)	0.098577
7	Beta β (rad /m)	188.4956
8	Characteristic impedance (ohms)	47.351-0.02476i

TABLE 5
MATLAB RESULT OF TEFLON AS A DIELECTRIC

	Coaxial parameters	Teflon (εr=2.1)
1	Shunt conductance (S/m)	εr =2.1
2	Shunt capacitance (F/m)	5.3078e-16
3	Series inductance (H/m)	9.8555e-11
4	Series resistance (ohm/m)	2.3675e-07
5	Gamma	9.3354
6	Alpha α (Np/m)	0.0952+182.104i
7	Beta β (rad /m)	0.095234
8	Characteristic impedance (ohms)	182.104

CHARACTERISTIC IMPEDANCE

The characteristic impedance is affected by relative permittivity (εr) for a homogeneous dielectric can be approximately computed by using electrical modeling n the coaxial cable and make a Matlab simulation to clarify the behavior of this impedance along the frequency band [14]. Characteristic impedance determines the amount of power transfer and attenuation effect along the coaxial cable transmission line; it also controls the amount of traveling, reflected and standing waves.

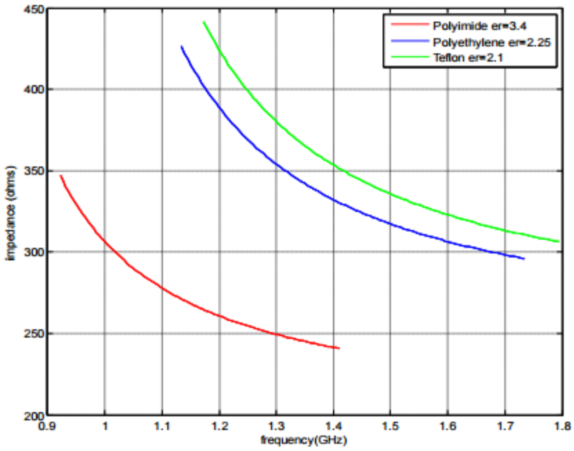

Figure 4: Characteristic impedance Vs. frequency

Fig.4. shows that the impedance characteristic gets less with the frequency increases, the impedance for the frequency bandwidth 0.9-1.8 GHz is relatively high when the frequency goes high to the thousands of gigahertz like satellite applications the impedance should be around (50-100) ohm. Polyamide has the lowest impedance, but polyethylene is more used material a dielectric since it is cheaper.

ATTENUATION

The term is "Attenuation", and it is measured in decibels per meter. One dB is roughly 25%, but it is on a logarithmic scale. The image above demonstrates how the polyamide is having less attenuation than the sleep of these tested dielectrics. It delivers the best performance whether at higher or lower frequency bandwidths. Of all figures of loss in coaxial cable, the radiation loss is generally the least important as only a real minuscule amount of force is generally radiated from the transmission line. Consequently, most of the focus on reducing loss is put onto the skin effect and dielectric losses. Since the resistor of the conductors and power is squandered in the dielectric which used for insulating the conductors, transmission line losses are affected to a lesser degree by the fabric utilized as the cable dielectric [9, 10].

The coaxial cable has a solid copper inner conductor of radius a = 1mm and a copper outer conductor of inner radius b. The outer conductor is much thicker than a skin depth. The dielectrics have different εr and the frequency 1 GHz. Letting the ratio outer to the inner diameter (b/a) vary from 1.5 to 10; generate a plot of the attenuation (in dB/m) versus the line impedance.

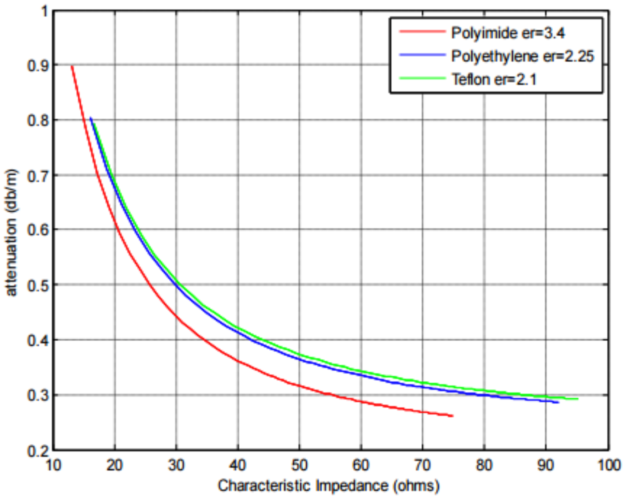

Figure (5): Attenuation of different dielectrics Coaxial cable has losses (Attenuation).

CONCLUSION

The mathematical analysis of the coaxial transmission line with three dielectrics mediums is represented based on Matlab software for the Teflon, polyamide and polyethylene. A detailed analysis has been to establish the essence of the dielectrics of the electrical model parameters, characteristic impedance and attenuation. This simulation software program experimentally depicts the operation of the coaxial transmission line with different dielectric mediums. The work has proven that the performance of the Polyimide has better results than the polyethylene and Teflon and it give less attention, practically the polyethylene has wider using because of its cheap price and easy to be made.

REFERENCES

[1] K. Praveen Kumar, K. SanjeevaRao, V. MallikarjunaRao, K. Uma, A.Somasekhar,C. Murali, "The effect of dielectric permittivity on radiation characteristics of co-axially feed rectangular patch antenna: Design & Analysis," International Journal of Advanced Research in Computer and Communication Engineering, Vol. 2,February 2013.

[2] Rishi Verma, A Shyam and Kunal G Sh, "Design and performance analysis of transmission line-based nanosecond pulse multiplier", Sadhana Vol. 31, Part 5, October 2006.

[3] RadimZajíˇcek and Jan Vrba, "Broadband Complex Permittivity Determination for Biomedical Applications",Czech Technical University in Prague, Dept. of Electromagnetic Field, FEE Czech Republic, 2014.

[4] George S. Kliros, "Simulated Performance of Conical Antennas Using Matlab-Based Finite-Difference Time Domain (FDTD) Code", Hellenic Air-Force Academy, Department of Aeronautical Sciences, Division of Electronics and Communication Engineering,Greece, 2014.

[5] Octavio Ramos-Leaños, Jose Luis Naredo and Jose Alberto Gutierrez-Robles.An Advanced Transmission Line and Cable Model in Matlab for the Simulation of Power-System Transients”, 2014.

[6] Alberto Godio, "Open ended-coaxial Cable Measurements of Saturated Sandy Soils", American Journal of Environmental Sciences, 2007.

[7] LuyanQian, Zhengyu Shan, “Coaxial Cable Modelling and Verification", Blekinge Institute of Technology, Sweden, 2014.

[8] Bernard Hyland, “An Improved and Simple Cable Simulation Model", 2014.

[9] F.C. Kahimba, R. Sri Ranjan, M. Krishnapillai." Impact of cable lengths on the accuracy of dielectric constant measurements by time domain Reflectometry", Volume 49, Canadian Biosystems Engineering, 2007.

[10] Jianmin Zhang, David J. Pommerenke, Richard E. DuBroff, Qinghua B. Chen." Causal RLGC(f) Models for Transmission Lines From Measured S-Parameters"Electromagnetic Compatibility ISSN :0018-9375, IEEE Transactions on Volume:52 , 2010.