Propagation Characteristics of Ultra High Frequency Waves in Narrow Gallery and Roadways of Coal Mines.

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Communication plays a pivotal role in every walks of life. Communication enhances production , productivity with due respect to safety of any production unit and industry. Moreover ,its importance increases manifold for a region like underground mines especially Coal mines, where safety concerned is paramount having tough topography, complex geological structure, narrow galleries and roadways surrounded by thick and rough side walls of hard coal structure and inflammable atmosphere due to prevalence of inflammable gas Methane.

Hitherto, there is not a single fool-proof wireless communication system designed so far to establish mine wide communications and for rescue operations in case of any eventuality - a regular phenomenon in underground coal mines. The reasons as explained above are as follows.-

1. Due to presence of inflammable & toxic gases i.e Methane and Carbon mono-oxide, the transmitting and receiving power of transceivers have restricted to 2 Watts only by safety regulation authority i.e DGMS in India.
2. The attenuation of radio-waves are prominent due to the zigzag and uneven side walls of gallery and narrow roadways and thick structure of roof (Seam).
   The objectives of the studies was to know the propagation characteristics of Electro-magnetic waves of varying frequencies in small galleries and narrow roadways of coal mines to find out Cut-off frequency above which radio waves cover maximum distance.

The most of the gallery and roadways of the coal mine are narrow and almost straight and looks like rectangular waves guide. The side walls and roofs (Coal seams) have very low electrical conductivity. Moreover near working face (coal face), the dimensions of roadways remain very small. and narrower.

First, the electrical properties of coal samples of many coal mines have been measured in varying frequency bands ,right from L.F to Microwaves region. The electrical conductivity of coal varies from 10^{-8} to 0.02 mho/m and dielectric constant approximately between 4-6 in 1KHz range and between 2-4 in 1 MHz range. With the increase of measuring frequency ,the dielectric constant of coal samples decrease slightly.

The theoretical studies of electromagnetic waves (e.m.) waves propagation of varying frequency have been done to evaluates the cut-off frequency of varying dimensions mine's galleries

1 The Propagation Characteristics of Electro-magnetic Waves through Mine Gallery alike Rectangular waveguide and Evaluation of Cut-of frequency

The gallery alike the rectangular waveguides with a perfect dielectric such as air,of magnetic permeability (U) and Electrical permittivity (E) inside the guide is considered Hfor the purpose of studying the characteristics and properties of waves guided in such system.. We suppose the width of the guide in x and y direction are “a” and “b” meters eand the dimension of the guide is of infinite extent in the Z-direction as shown in Fig 1

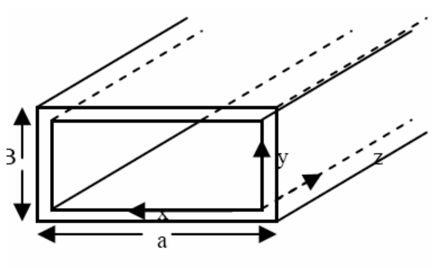

fig 1 A section of a rectangular wave –guide (Gallery’s entry)

We assume that there exists wave-propagation in the +z direction so the rectangular (1.a)components of the electric and magnetic fields vectors E and H have expressions;-

$\bar{E}x = \bar{E}xo\, e^{-\gamma z}$ --------- (1.a) $\quad$ $\bar{H}x = \bar{H}xo\, e^{-yz}$ --------- (1.d)

$\bar{E}y = \bar{E}yo\, e^{-\gamma z}$ --------- (1.b) $\quad$ $\bar{H}y = \bar{H}yo\, e^{yz}$ --------- (1.e)

$\bar{E}z = \bar{E}zo\, e^{-yz}$ --------- (1.c) $\quad$ $\bar{H}z = \bar{H}zo\, e^{-yz}$……… (1.f)

Where γ^* = Complex Propagation Constant. and in general mentioned as

$\gamma = \alpha + i\,\beta$

In the case of rectangular wave guide, the solution of the components of the electric field intensity-vector E must satisfy the following boundary conditions

Ex= Ey = 0 at y=o and Y=b. (2.a)

Ey= Ez at x=0 and x=a (2.b)

The electrical and magnetic field configurations in the TE wave propagation in the rectangular waveguides are as follows:-

$\bar{E}x(x,y,z,) = iwu/h^2\ \hat{C}\,(n\pi/b)\cos(m\pi/a\ .x)\sin(n\pi/b\ .y)\, e^{-i\beta z}$ (3.a)

$\bar{E}y\,(x,y,z) = -iw\acute{u}/h^2\ \hat{C}(m\pi/a)\sin(m\pi/a.x)\cos(n\pi/b\ .y)\, e^{-i\beta z}$ (3.b)

$\bar{H}x\,(x,y,z) = i\beta/h_2\ \hat{C}\,(m\pi/a)\sin(m\pi/a\ .x)\cos(n\pi/b.x)\, e^{-i\beta z}$ (3.c)

$\bar{H}y\,(x,y,z) = i\beta/h_2\ \hat{C}\,(n\pi/b)\cos(m\pi/a\ .x)\sin(n\pi/b\ .y)\, e^{-i\beta z}$ (3.d)

$\bar{H}z\,(x.y.z) = \hat{C}\cos(m\pi/a.x)\cos(n\pi/b.y)\, e\text{-}i\beta z$ (3.d)

And likewise field configuration of inside the rectangular waves guide corresponding to Tmn waves are as follows.”

$\bar{E}z\,(x,y,z) = \hat{C}\sin(m\pi/b\ .x)\sin(n\pi/b.y).\ e_{-i\beta z}$ (4.a) $\bar{E}x\,(x,y,z) = -ib/h_2\,\hat{C}\,(m\pi/a)\cos(m\pi\pi).x\sin(n\pi/by)\ e_{-i\beta z}$ (4.b)

$Ey\,(x,y,z) = -i\beta/h_2\hat{C}\,(n\pi/b)\sin(m\pi/a..x)\cos(n\pi/b.y)\, e_{-i\beta z}$ (4.c)

$Hx\,(x,y,z) = iwe/h_2\ \hat{C}\,(n\pi/b)\sin(m\pi/a)\ \cos(n\ \ /b\ .y)\, e_{-i\beta z}$ (4.d)

$Hy\,(x,y,z) = -i\acute{\omega}€/h_2\, C\,(m\pi/a)\cos(m\pi/a.x)\ \sin(n\pi/b.y)\, e_{-i\beta z}$ (4.e)

It is very clear that these sets of equations that no TEM Wave, for which there is no Z components of both E and H could possible propagate within a single conductor-guide such as rectangular waveguides.

Now ,we examine the propagation characteristics of the TEmn and TMmn waves guide in a rectangular guide,

The electrical field intensity –vector E could have Ex component ,i.e component in the +Z direction which is assumed to be the direction of wave-propagation.

The wave-equation for intensity vector Ex is

$$ə^2x /əx^2 + ə^2d/ ə^2y = -h^2 Ex, \quad (5)$$

where in case of a perfect dielectric occupying the space inside the guide,

we get $$h^2=y^2-k^2= y^2+ w^2μ€ \quad (6)$$

in case of rectangular waveguide,

$$Ez(x,y,z) =Ezo(x,y)e^{-yz}.. \quad (7)$$

Substitution of Eq 7 i into Eq.5 gives,

$$d^2Ezo/dx^2+ d^2Ezo/dy^2 =- h^2/Ezo \quad (8)$$

The solution of Eq.(8) is easily obtained by substitution method of separation of variables. We could write

$$Ezo(x,y) =X(x)Y(Y) \quad (9)$$

Where x is a function of x alone and y is a function of y alone.

Substitution of ths eq. (9) into eq .(8) the gives

$$Y d^2X/dx^2 + Xd^2Y/dy^2+h^2XY =0 \quad (10)$$

We could write

$$I/X d^2X/dx^2 +h^2 = -1/Yd^2Y/dy^2 \quad (11)$$

The Eq.11equates a function of x to a function of y .The only way in which such a relation could hold for all values of x and y,is that each side of Eq.11 is equal to some constants ,say A^2

So,

$$1/x. d^2X/dx^2 + h^2 = A^2 \quad (12)$$

$$1/y . d^2Y/dy^2 = -A^2 \quad (13)$$

A general soln. of eq 12 is

$$X(x) = \hat{C}_1 \cos Bx+ \hat{C}2 \sin Bx \quad (14)$$

Where we have put

$$B^2=h^2-A^2 \quad (15)$$

$$So , B^2+A^2 = (mπ)/a)^2 +(nπ/b)^2 \quad (16)$$

Substituting the eq. into eq and by solving for the value γmn

we get,

$$γmn= \sqrt{} B^2+A^2 \_ w^2 μ€ == \sqrt{}(mπ/a+nπ/b-w^2ue) \quad (17)$$

Assuming dielectric occupying space within the rectangular wave guide supposed to be perfect dielectric.

Eq 17 thus defines the propagation of constant for a rectangular waveguide for both TEmn and TMmn waves..

It is obvious that for very low frequencies ,for which $w^2μ€$ is small, $γ_{mn}$ will be a real number. However, if y is real number them ß in eq 1. must be zero and hence there is no phase – shift along the rectangular waveguide. It means that there is no wave motion along the rectangular waveguide. However. as the frequency is increased , a value of ώ will be reached which makes the expression radical on the right hand side of eq (1.) equal to zero. This value 0f radian frequency is called as cut-off frequency wo corresponding to TMEmn and TMmn mode in a rectangular waveguide and given by

$$w_c = 1/\sqrt{}με . \sqrt{}(mπ/a)^2+ (nπ/b)^2. \quad (18)$$

The corresponding cut-off frequency $v_c =w_c/2π$ i.e, the frequency below which wave propagation will not occur is given by;-

$$\H{υ}c =w_c/2π= ½ π\sqrt{} υε \sqrt{}(mπ/a)^2+ (nπ/b)^2 \quad (19)$$

Or the corresponding cut-off wavelength is given by

$$λc= Vp/Vc = 1/vc_{\sqrt{}} υε = 2II/(mII/a) +nII/b)^2. \quad (20)$$

Where Vp is the phase velocity of uniform plan waves propagating in a perfect dielectric media of permittivity e and permeability u and given by

$$Vp =1/ \sqrt{}μ€ \quad (21)$$

According to the Eq 20 the cut-off frequency for any TEmn and TMmn mode is given by

$$\H{υ}c = Vp /2ab .\sqrt{} m^2b^2 +n^2a^2 \quad (22)$$

2 Attenuation of High Frequency(H.F>0 and Very High Frequency (VHF,300-3000MHz) Electromagnetic Waves.

Actually the attenuation due to reflection ,dispersion or scattering of waves from walls and roof of the gallery in case of Very high frequency and Ultra high frequency waves transmission is negligible as the energy of the multiple wave length of propagated e.m waves near walls or roof is negligible as the restricted transmitting power is 2Watts so reflected waves and scattered waves have no effects on traveling waves.

Based on the evaluation of cut-off frequency for propagation of Electro-magnetic waves in rectangular alike mines galleries and narrow straight roadways, experiments were carried out in some coal mines with transceivers of variable transmitting and receiving frequencies matched with the dimension of the galleries and roadways. Commensurate with the dimension of gallery ,the transceivers having cut-off frequency as evaluated from formula were chosen for communications among mine personnel roving along gallery.

One of the authors and his team have already conducted field trials with Citizen Band (27-29 MHz), H.F(68- 88MHz) & V.H.F(400-500MHz.) sets of Transmitting power of 2Watts inside narrow galleries and passages of varying dimensions on Nadira mine under Mahanadi Coalfields Ltd,Talchar,India. & Sudamdih and Moonidih Mines of B.C.C.L.,India.

It has been observed that in a almost straight narrow roadway of mines having dimensions approx. 3meter width (opening) and roof height of approx.3 meter, the transceivers of High Frequency band (Approx 96 MHz and above, Transmitting Power 2 watt) propagates to about 300 meters compare to about 90 meters in case of transceivers of Citizen bands(27.2 MHz,2watt). More attenuation occurs in case of citizen band transceivers ,if set is near side walls of the galleries. The reason is simply that even only one mode in case of low frequency (27 MHz) gets distorted.

Transceivers of 400 MHz (V.H.F.,2 watt) were tried in galleries (Dimensions 3X3 m, a &b) of Nadira Coal Mine under Mahanadi Coalfields Ltd.,Talchar and voice conversations up to about 300 meters were distinct and clear and audible.Experiments were carried out by in same locations with transceivers of 27.2 MHz,2watt , and communications up to only about 100 meters could be established.

3 Conclusion

The appropriate wireless communication to covers maximum distance inside narrow galleries and roadways of coalmines with a limited power of two watts of Transceivers needs selection of frequencies above the cut-off frequency accordingly to the dimension of gallery. Below cut-off frequency, the waves suffers absorption from surrounded non-conductive walls and concert coal strata (roof).

4 References

4.1. Y.P.Zhang and Y.Hwang, " Theory of Radio Wave Propagation in Radio Tunnels,IEEE Trans Veh Technical,US),47,1998,pp.1027.

4.2. L.K.Bandyopadhyay.P.K. Mishra,S.Kumar,D.selvendran &S.K.Chauliya, Studies on Radio Frequency Characeristics for Underground Coalmine Communication," Volume 36,Indian Journal of Radio & Space Physics,Oct2007, pp418-422.

4.3. S.Ramo,John R. Whinnery 7 Theodore.Van.Duzer,"Fields and Waves in Communication Electronics," Third Edition,John wiley & Sons,U.K.,1994,pp417-428.

4.4. L.Deryck,"Natural Propagatin of Electromagnetic Waves in Tunnels,"Vehicular Technology,IEEE Transactions, Volume 27,August 1978,pp1-4.