Determination of RF Energy Threshold Level for Ignition of Electro Explosive Devices.

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***Abstract*-Electric Detonators with its two terminal paired cable may act as an efficient receiving antenna. Radiated field from other sources may optimum level of current in the cable and in turn accidental detonation may occur. Present work is focused on estimation of hazardous field strength level.**

***Keywords*-Electric detonator,effecive radiated power,mining enviroment.**

I. Introduction

In recent times RF wireless instruments are taking entry in to mining environment. Use is mostly for communication. It may be for voice or remote equipment control. Environment in the mining is totally different from open space environment. Numbers of chemical components in the form of inflammable gases are present in mining environment. Also present are electro explosive devices or detonators. Detonators are used for deliberate explosion to blast the rocks. Any energy emitting source with needed amount of energy can initiate ignition of gases or explosion of detonators and cause devastating damage to human lives other than financial loss [1],[2],[3]. So it has been prime concern to the authority to ensure a threshold level of energy which can be permitted to emit in mining environment. In this context RF experiments have been carried out for detonators

II. Background of Work

Discussion here is focused on to coal mine activities There are lot of activities which can have very effective use of EM(RF) technologies of today. To name some area of use are

- communication among the personnel on surface and personnel in underground
- Instrument control
- Continuous updating of data on every parameter underground.
- locating of miners at the time of disaster

ASSOCIATED UNDESIRABLE EFFECTS

Mining environment, be it underground or surface, is quite different from normal free space environment. In underground there are pockets where hazardous gaseous components are present. On the surface electric detonators are most potential device for inadvertent accidents.

Up to very recently, any thinking for precaution is guided by the idea of accidental fire. But now use of wireless technology is compelling the authority for evaluation of safety aspect of wireless devices. Very reason is, an EM wave carries energy in its field. In the propagation path EM energy gets coupled to all sorts of matters, particularly the matters with conductive properties. In conductors current is induced due to EM field and it may reach to the level of detonation. So it is essential to have an idea of radiated field strength which can create inadvertent ignition of detonators.

PRECAUTIONERY MEASURES

In general practice mining authorities ensures intrinsic safety of each and every instrument which is going to be used in mining environment. Till date, intrinsic safety ensuring process primarily considers electrical and mechanical aspects. Unfortunately, no guideline is available in the country for ensuring safe character of wireless instruments or effect of electromagnetic energy in that sense. Where as this type of instruments are slowly taking entry into mining industry. So it becomes essential to determine safety properties of these instruments.

Recently SAMEER Kolkata took part one such exercise for estimation of RF power level where detonation is initiated. Aim of this exercise was to verify standing of the instruments mentioned below in terms their potential to initiate accidents.

- LAN instruments in the form of WI-FI system.
- VHF and MF cross band communication repeaters
- Communication system which use magnetic coupling

DETONATION MECHANISM

In detonator fuse head is encapsulated in a metal cylinder which also contains explosive material. Fuse head is a resistance and detonation current is fed from a battery by 2.5 mtr of paired two wire cable. Resistance is surrounded by explosive material and energy for initiation of detonation is thermal. On flow of requisite current resistance gets heated and raised the level of heat to the point of detonation.

III. THEORETICAL ANALYSIS

In the attempt of determination of threshold EM energy level, experiment is considered best way to facilitate the decision. To have the reference power for detonation, first DC experiment is carried out.

For RF experiment, frequencies were considered as the frequencies of instruments mentioned above. These frequencies are

- 470 KHz for magnetic coupling
- 147.32 MHz for cross band repeater
- 2.4GHz and 5.8 GHz for WI-FI system

Due to facility limitations experiment was carried out up to 1GHz. RF power is fed to detonator cable from signal source and amplifier combination. Power is varied to note the point of detonation. Then keeping the instruments setting as it is same power is measured by power meter. Test set up block diagram is shown in Fig.1.Since we can not measure actual power dissipated in detonator resistance it is determined by calculation.

At 470 KHz, length of the detonator cable is short in terms of wave length. Therefore quasi static or static approach is valid. From power measured at 50Ω open circuit voltage of source is found. Then for that open circuit source voltage actual power delivered to detonator resistance, in comparison to total power delivered, is estimated and results are given in tabular format.

At 147.32MHz and 1Ghz static approach is no longer valid and transmission line approach is adopted. To estimate actual power delivered [4]. Line parameters are extracted first from the measurement of Z_{SC} and Z_{OC}, short and open circuit impedance of 2.5mtr two wire lines. Actual power dissipated at fuse resistance is found using the equation

$$V_L = 2 \times V_G \frac{Z_O Z_L}{(Z_O + Z_G)(Z_O + Z_L)e^{\gamma l} - (Z_O - Z_G)(Z_O - Z_L)e^{\gamma l}}$$

V_L is load end voltage, V_G is open circuit generator voltage, Z_O is characteristic impedance of the line, Z_L is load impedance, γ is propagation constant of the line.

For a power which detonates the device, source power is measured by power meter. Power meter is of 50 Ω. So, giving Z_L a value 50 Ω V_G is calculated from above equation. Once V_G is known then load voltage is found and inturn actual power dissipated in detonator resistance is calculated.

IV. RESULTS

At DC, firing power level varies from 196.92mw to 133.77 mW for fuse head ranges from 1.22Ω to 1.82Ω. Data for RF power are as given in tables below. Table1 shows power dissipated by fuse head at detonation.

Table 1: Power levels at DC with detonation probability

Name of detonator	Average Resistance of fuse head (Ω)	Power for 50% firing probability (mw)	"No Fire Power" with 95% confidence interval	
			For 0.1% firing probability ((mw)	For 0.01% firing probability (mw)
CV	1.82 Ω	133.77	50.94	43.35
CDD	1.86 Ω	177.31	101.19	93.17
CDD	1.22 Ω	196.92	124.61	116.69
APPDD	1.91 Ω	151.63	59.57	51.21

Actual powers dissipated at fuse head at RF power of selected frequencies are shown in table2, 3 and 4.

Table2. Actual power dissipated at fuse head at 470KHZ

P_{AMP}	V_{oc}	R_{CKT}	P_{DET}	D_{STAT}
10.02	31.66	55.41	0.59	Detonated
9.35	30.59	55.41	0.55	Detonated
7.96	28.22	55.41	0.47	Detonated
6.32	25.15	55.41	0.37	Detonated
5.02	22.41	55.41	0.30	Detonated
3.99	19.98	55.41	0.24	Detonated
3.17	17.80	55.41	0.19	Detonated
2.52	15.87	55.41	0.15	Detonated
2.83	16.81	55.41	0.17	Detonated
2.64	16.24	55.41	0.16	Detonated
2.58	16.05	55.41	0.15	Detonated
2.52	15.87	55.41	0.15	Detonated
2.40	15.51	55.41	0.14	No detonation

P_{AMP} is total power output of amplifier V_{oc} open circuit generator voltage, R_{CKT} total circuit resistance with detonator resistance and source impedance, P_{DET} power at detonator fuse head, D_{STAT} detonation status.

Table3: Actual power dissipated in fuse head at147.32 MHz

Power input to detonator cable in dBm	Power input to detonator cable in W	Power at 1.82Ω detonator resistance in (W)	Detonation status of detonator
51	125.89	0.642	yes
49	79.43	0.405	yes
48	63.09	0.322	yes
47.8	60.26	0.307	yes
47.6	57.54	0.293	yes
47.4	54.95	0.280	yes
47.3	53.70	0.274	yes
47.2	52.48	0.268	no
47	50.12	0.255	yes
46	39.81	0.203	yes
45	31.62	0.161	yes
43	19.95	0.102	no
41	12.59	0.064	no
40	10.00	0.051	no
36	39.81	0.021	no
31	12.593	0.0064	no

Table4. Actual Power dissipated at fuse head at 1GHz

Amplifier output (dBm)	Amplifier output (W)	Power at 1.82Ω detonator resistance (mW)	Detonation status
49.49	89	160	No detonation
49.34	86	155	No detonation
48.92	78	140	No detonation
46.72	47	85	No detonation

Somewhat opposite results have been found in 1GHz experiment. Though estimated power at fuse head is in detonation level, it did not explode. Most probably, the capacitance formed between fuse head and detonator cylinder wall provides a least impedance path for the microwave signal and fuse head get bypassed.

In actual mining environment a detonator will receive power from field due to wireless devices. In experiment, source impedance is always 50Ω. For radiated field three types of source impedance can be assumed [5].

- Very low impedance due to dominant magnetic field
- Very high impedance due to dominant electric field
- Free space impedance due to electromagnetic field

These assumptions are indicator of the position of the detonator from radiating source. When actual power for detonation is determined from direct measurement, radiated field strength also can be estimated considering above three assumptions. Table6 below shows the source power strength for dominant magnetic and free space event.

Table5. Predicted Power levels at fuse head for different source impedances

Power input to detonator cable in dBm	Power input to detonator cable in mW	Power at 1.82Ω detonator resistance in (W)	
		For Z_g =0Ω	For Z_g =377Ω
51	12.59	0.643	0.651
49	79.43	0.397	0.411
48	63.09	0.316	0.326
47.8	60.25	0.302	0.312
47.6	57.54	0.288	0.298
47.4	54.95	0.275	0.284
47.3	53.70	0.269	0.278
47.2	52.48	0.263	0.272
47	50.12	0.251	0.259
46	39.81	0.199	0.206
45	31.62	0.158	0.164
43	19.95	0.100	0.103
41	12.59	0.063	0.065
40	10.00	0.050	0.052
36	39.81	0.021	0.021
31	12.59	0.0063	0.006

It is seen from the table that in comparison with 50Ω source impedance fuse head will receive more power when source impedances are of dominant magnetic and electromagnetic.

From the experimental results and theoretical estimation , effective power level of an intentional radiator can be determined which will not create inadvertent accident in mining environment.

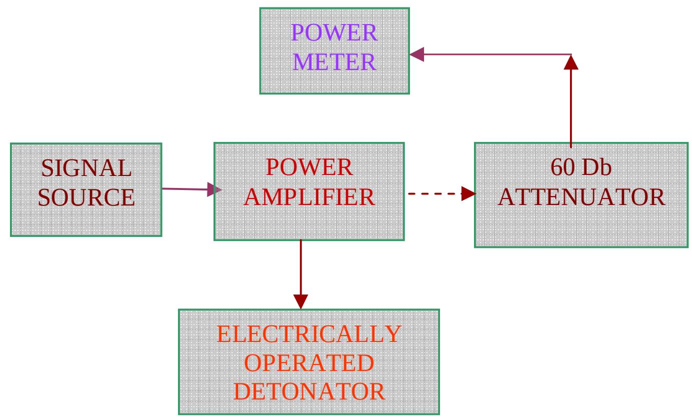

Fig. 1.Block diagram of Measurement set up

V. CONCLUSION

This investigation has been carried out only with electric detonator. But gaseous environment of underground mines is also prone to be ignited by EM energy. Non hazardous level for gaseous environment is yet to be investigated and that opens the area of further activity.

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REFERENCES

[1] R.H. Thompson, J.G. Stuart and A. W. Cipkins "A Study of RF Hazards at Low and medium Frequencies to blasting in Underground Coal Mines" A Mining Research Contract Report, Franklin Research Center, Philadelphia.

[2]. Institute of Makers of Explosives " Safety Library Publication 20 "

[3]. Norabel Ignition System " Electric Detonators"

[4] D.K.Cheng , "Field and Wave Electromagnetics" 2e 1999,Addison Wesley .

[5] F. M. Tesche,M.V.Ianoz,T.Karlsson "EMC Analysis Methods and Computational Models",1e 1997.,John Wiley & Sons, Inc. New York.

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