AMPLITUDE STATISTICS OF ELECTROMAGNETIC NOISE IN COAL MINES*

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Abstract

A system for measuring amplitude probability distributions (APD's) of electromagnetic noise in coal mines is described and typical APD's from an underground coal mine are presented. The APD is a basic statistic required for the design and analysis of communication systems, especially those intended for use in noisy environments, and where neither overdesign nor underdesign is acceptable. The rms and average field strengths are obtained by integration of the APD, and examples are shown at several frequencies. All field strength levels are given in absolute units. Selected frequencies cover the range from 10 kHz to 32 MHz.

I. Introduction

Ambient electromagnetic (EM) noise often limits radio communications in mines. Therefore, it is necessary to know the detailed statistical characteristics of the interfering noise in order to design optimum performance receivers and effective error-correcting coding schemes. The cumulative amplitude probability distribution (APD) of the received noise envelope is one of the most useful statistical descriptions of the noise process for the design and evaluation of a telecommunication system operating in a noisy environment [1,2].

This paper describes the system used to measure magnetic field noise in a coal mine. The system is an extension of one designed by Matheson [3]. Typical APD's are presented. Figures on Rayleigh graph paper show the fraction of the time that this noise exceeds various levels. This particular Rayleigh graph paper has scales chosen so that Gaussian noise (e.g., thermal noise) plots as a straight line with a slope of $-\frac{1}{2}$. Noise with rapid large changes in amplitude (e.g., impulsive noise) will have a much steeper slope, typically -4 or -5, depending on the receiver bandwidth. The APD's are then integrated to give rms and average values of the field strength, according to the equations

$$H_{avg} = -\int_{0}^{\infty} H \, dp(H)$$

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and

$$H_{rms} = \left\{ -\int_{o}^{\infty} H^2 \; dp(H) \right\}^{\frac{1}{2}}$$

where H represents the magnetic field strength of the noise and p is the probability that the measured field strength exceeds the value H. These quantities are also dependent upon the measurement bandwidth, the length of the data run, and possibly other parameters. Finite series are actually used for the numerical integration. The rms and average values so arrived at are identified on each graph.

II. Measurement and Data Processing Instruments

The principal parameter measured was magnetic field strength. The antennas used were electrostatically-shielded loops with impedance transforming baluns. The outputs of the baluns were fed into commercial, battery-powered field strength receivers. The characteristics of the receivers used for our measurements are listed in Table I.

T.. i-f outputs from the field strength receivers were converted from 455 kHz to 40 kHz using mixers. They were recorded by a portable magnetic tape recorder. The tape speed on record and on playback was 15 inches per second (ips). At this speed, the portable recorder response band was from 100 Hz to 56 kHz at the 2 dB points in the direct recording mode. The dynamic range of the recorder was 48 dB. The tape was then transcribed through another tape recorder whose servo system could take out the flutter and wow introduced by the portable recorder. The data processing system consisted principally of the analog magnetic tape recorder for a playback unit and an instrument which provided a direct digital display of the percentage of the time each of 15 levels, 6 dB apart, were exceeded.

The bandwidth of the whole system was primarily determined by the data processing system and was found to be about 2 kHz. The dynamic range of the whole system, including the recording and the data processing systems, was primarily limited by the magnetic tape recorder to about 45 dB. The system used for recording and data processing is shown in Figure 1.

The calibration of the whole system, including the loop antennas, field strength meters, mixers, magnetic tape recorders, the impedance transforming amplifiers, and the digital counter was performed by immersing the receiving loop antennas in a known f: d, generated at the NBS field calibration site. Thus all levels of field strength are given in absolute units.

III. Amplitude Statistics of EM Noise in a Coal Mine

Many APD's of magnetic field noise were taken during actual operation of Robena No. 4 Coal Mine, Waynesburg, Pennsylvania, on December 5th and 7th, 1972. The loop antennas were placed about 300 meters from the face area. Three orthogonal components of magnetic fields were measured at eight frequencies ranging from 10 kHz to 32 MHz. Fig. 2 shows a typical APD at 10 kHz underground, and Fig. 3 shows a corresponding APD at the surface above the operating mine. Numerous measurements have shown that although this noise in a mine is strongly time dependent, if the noise is averaged over a period of about 20 minutes, then the resulting values are fairly repeatable from period to period.

The rms and average values result from about 20 minutes of data and are indicated in Fig. 2 and Fig. 3. Rms and average values f noise at selected frequencies from 10 kHz to 32 MHz are shown in Fig. 4.

The principal value of the APD curves is that they show statistically how much the magnetic field varies at different times. For instance, at 10 kHz underground, magnetic fields 50 dB above one microampere/meter will be exceeded only .0001 percent of the time, while fields 5 dB above one microampere/meter will be exceeded 99 percent of the time. An rms value of 24 dB above one microampere/meter will be exceeded (in this case) about 36 percent of the time. The surface data show a corresponding rms value of 3 dB above one microampere/meter.

References

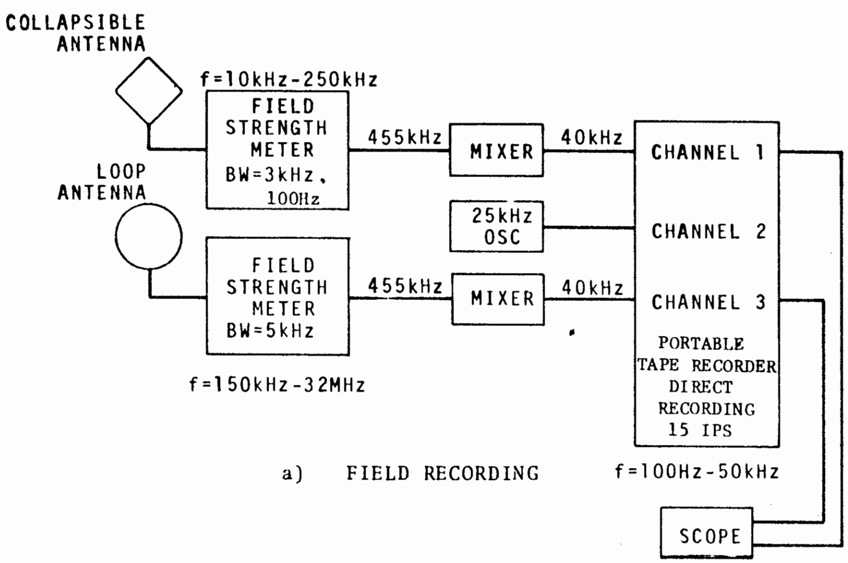
1. W.Q. Crichlow, et al. (1960 NBS Monograph 23).

2. W.I. Thompson, III (1971 DOT Rep. DOT-UMTA-71-3).

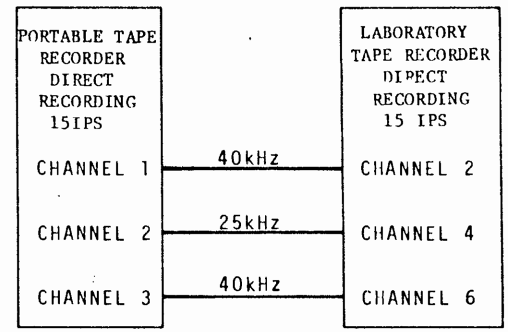
3. R.J. Matheson (1970 IEEE Trans. on EMC, EMC-12, p. 151).

Field Strength Meter	A	B
Frequency Coverage	10 kHz-250 kHz	150 kHz-32 MHz
IF Bandwidth (Impulsive)	Narrowband 110 Hz Broadband 2.7 kHz	5.0 kHz
Dynamic Range	67 dB	60 dB
Spurious Response Rejection (Image, IF, etc.)	> 50 dB	> 60 dB

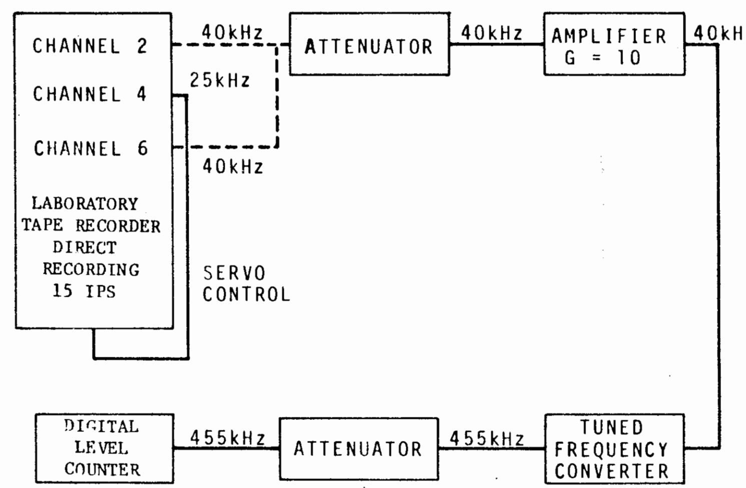
TABLE I CHARACTERISTICS OF THE FIELD INTENSITY RECEIVERS



a) FIELD RECORDING



b) TRANSCRIBING



c) APD PROCESSING

Fig. 1 THE SYSTEM FOR a) FIELD RECORDING, b) TRANSCRIBING, AND c) APD PROCESSING

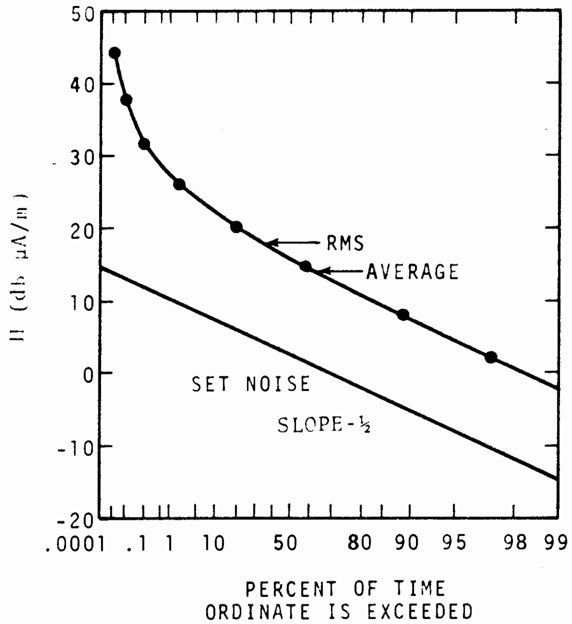


Fig. 2 APD OF FIELD STRENGTH, H, AT 10 kHz (UNDERGROUND)

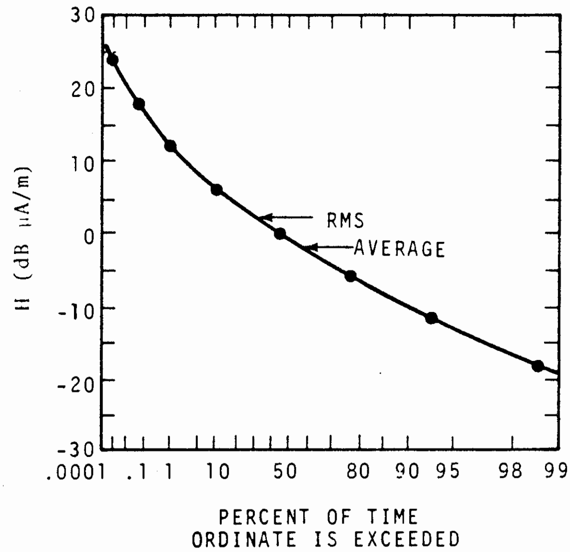


Fig. 3 APD OF FIELD STRENGTH, H, AT 10 kHz (SURFACE)

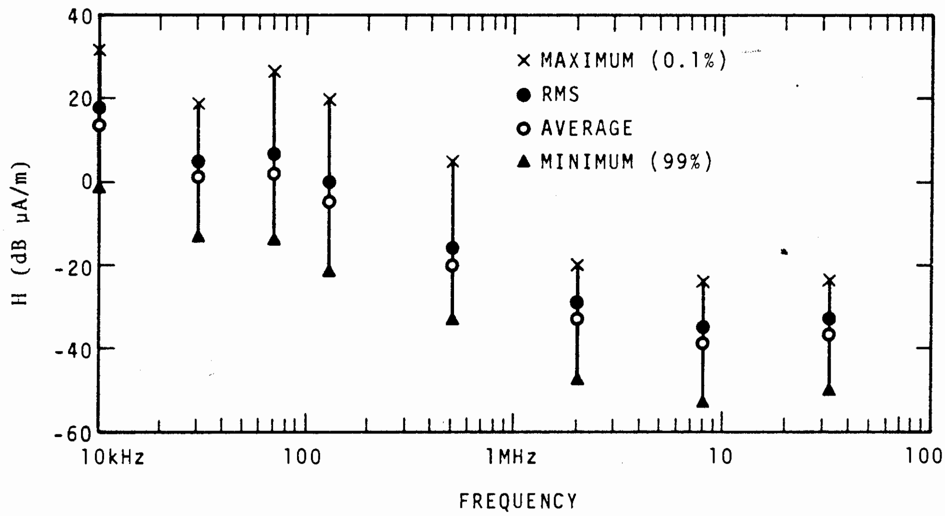


Fig. 4 VARIATION OF FIELD STRENGTH, H (UNDERGROUND)