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# Effect of Ultralow Frequency Signaling on Blasting Array Current

By Kenneth E. Hjelmstad and Russell E. Griffin

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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## CONTENTS



## ILLUSTRATIONS

## UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

| | | | |
|---|---|---|---|
| A | ampere | m | meter |
| ft | foot | mA | milliampere |
| Hz | hertz | W | watt |

# EFFECT OF ULTRALOW FREQUENCY SIGNALING ON BLASTING ARRAY CURRENT

By Kenneth E. Hjelmstad[1] and Russell E. Griffin[2]

## ABSTRACT

The U.S. Bureau of Mines (USBM) has developed an electromagnetic (EM) fire warning alarm system for underground mines. The system generates a magnetic field for through-the-earth signal transmission to microreceivers carried by individual miners.

EM fields can induce electric currents in metallic conductors; if an EM transmitting antenna and an electric blasting cap array are too close, the field could induce a current in the blasting array and cause an unintentional initiation of the electric detonators. The USBM conducted tests that define the safe and unsafe regions for using electric detonators near the transmitting antenna of the warning alarm system.

The minimum safe distance between a transmitting antenna and a blasting array is the distance where the induced electrical current in the blasting array is 50 mA, which is the safe current level specified in Federal mine safety regulations. Tests indicate that at transmitting power levels of 100- and 1,000-W, separation distances of 9 and 21 m, respectively, were required. These distances are small compared with the dimensions of a mine. Thus, the tests indicate that, with proper placement of the transmitting antenna, the warning system can be used safely in the proximity of blasting arrays.

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## INTRODUCTION

The USBM has developed an EM fire warning alarm system for underground mines as part of its program to enhance worker safety in mines (*1*).[3] The warning system employs the transmission of an ultralow frequency (ULF) EM signal to small personal receivers carried by miners to alert them to the threat of fire or other emergencies. Tests of the EM fire warning system indicated that the 100-W EM signal can effectively penetrate over a mile of mine rock and be effectively received in underground mine entries. The signal did not adversely affect storage of data on a computer diskette that was carried into the mine during prototype testing. Therefore, it is unlikely that in-mine computer systems will be affected. The technology has been successfully commercialized, and at least three firms are marketing systems based on USBM research.

Like commercial AM- and FM-radio signals, the EM field created by the warning alarm system has the potential for generating electric current in a metallic conductor (*2*). Tests were conducted to determine if there could be a threat to personnel or property from electrical current being generated in a blasting array or electric detonators by the EM field of the fire warning system and subsequently causing an unintended initiation.

## BACKGROUND

A general rule for blasters regarding EM fields states that the wave length of the EM signal must approximate the half-length of the electric detonator or blasting array to effectively couple and generate an electrical current in a circuit containing an electric detonator (*3*). Unlike the wavelength of medium-frequency commercial radio signals, the wave lengths of the ULF signals of the fire warning system are much greater than typical blasting array dimensions and are less able to effectively couple and generate electrical current in a blasting array.

The maximum safe level of stray current in a blasting array or electric detonator has been set by the U.S. Mine Safety and Health Administration (MSHA) at 50 mA. Title 30 of the U.S. Code of Federal Regulations (CFR), Part 57.6000-.6960, contains the mandatory blasting safety regulations for underground metal and nonmetal mines established by MSHA. Extraneous electricity regulations for loading practices state that "if extraneous electricity is suspected in an area where electric detonators are used, loading shall be suspended until tests determine that stray current does not exceed 0.05 A through a 1-ohm resistor when measured at the location of the electric detonators. If greater levels of extraneous electricity are found, the source shall be determined and no loading shall take place until the condition is corrected" (30 CFR 57.6600). The level of electrical current at which the ordinary electric detonator is designed to be initiated is about 250 mA. Research conducted by the Institute of Makers of Explosives (IME) defined the amount of blasting array current generated by EM fields of commercial AM- and FM-radio signals at known distances from the blasting array (*3*). The safe and unsafe distances at various power levels were established and the results documented and illustrated.

Tests were conducted by the USBM to establish the amount of electrical current generated in a simulated blasting array by the ULF signal from the fire warning alarm system. The results of these tests were used to generate safe and unsafe region graphs. These graphs, test procedures, and test results are presented in the following sections.

## EXPERIMENTAL PROCEDURE

A large simulated blasting array, made up of No. 22 single-strand copper wire, was formed in the shape of a rectangle, 7.6 m (25 ft) wide by 68.5 m (225 ft) long. The 152-m (500-ft) perimeter loop would normally exceed the size of most blasting arrays, but serves to approximate maximum conditions for capturing magnetic flux from an EM source. Blasting leg wires extending from the face being blasted to the blaster's location often exceed 225 ft;

[3]Italic numbers in parentheses refer to items in the list of references at the end of this report.

however, the leg wires are not typically configured in a way that captures magnetic flux.

A 1-ohm resistor contained in series within the blasting array was used to simulate a 1-ohm resistance of an electric detonator. A voltage check of the resistor indicated a negligible background of EM noise, which generated a stray current of less than 1 mA. A 49-m (160-ft) diameter eight-turn-loop antenna for the EM fire warning system transmitter was placed adjacent to the blasting array on a flat grassy area away from significant EM noise (fig. 1). The transmitting antenna was used to transmit EM signals at various power levels from 10 to 200 W. Transmissions of signals at 990 and 2,970 Hz were made at various power levels to determine the effect of frequency on the level of current generated in the blasting array. Distances between the transmitting antenna and blasting array were varied to determine the safe and unsafe areas for placement of the blasting array adjacent to the antenna. This procedure was somewhat similar to the method used to produce the safe and unsafe region graphs in previous research (*3*).

While an EM signal was transmitted for the fire warning alarm system, a voltmeter was used to measure voltage drop across the 1-ohm resistor, simulating a blasting cap within the blasting array. The array current was then determined by use of Ohm's law, the known resistance, and the voltage drop across the resistor. The current generated in the blasting array by the EM field of the fire warning alarm system varied as a function of power level, distance between the antenna and array, and transmitting frequency. The antenna and array were coplanar during the tests, and according to previous findings (*3*), the maximum array pickup of stray current occurred when the array was in the plane of the antenna. If a coaxial placement of antenna and array existed in a mine (*1*), the lesser coupling tendencies for this configuration could be assumed to pose less of a safety threat than the coplanar conditions of the tests.

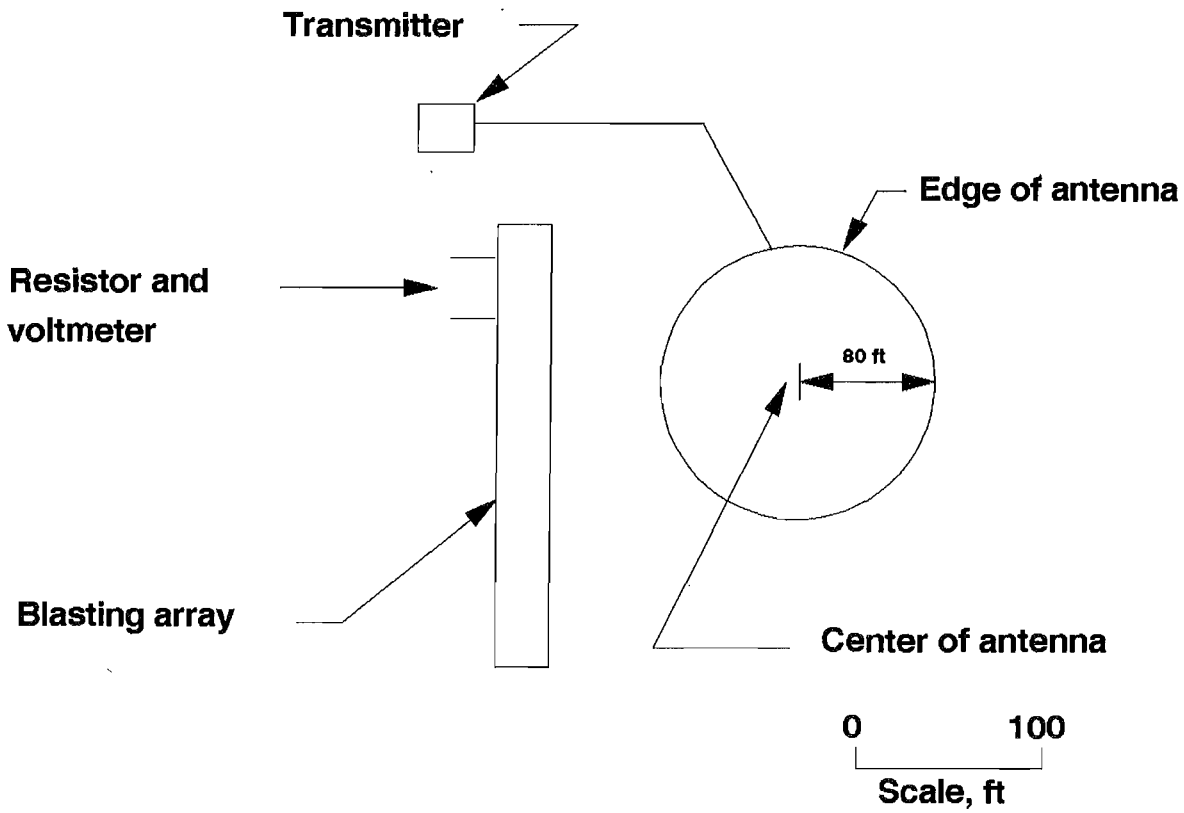


Figure 1.—Test setup of simulated blasting array.

## EXPERIMENTAL RESULTS

The electrical current generated in a blasting array by an AM-radio signal was determined previously through research and documented (*3*). A graph based on these prior results (fig. 2) shows the safe and unsafe areas for blasting array placement near an AM transmitter. The line defining safe and unsafe areas also defines the separation distance between antenna and array that limits stray electrical current levels in the blasting array to 50 mA. Similar graphs were prepared from the results of tests conducted by USBM researchers during tests with the ULF fire warning alarm system and a simulated blasting array.

The magnitude of electrical currents generated in the blasting array by the 990- and 2,970-Hz signals of the ULF fire warning system were established at various antenna-array spacing and transmitting power levels. The safe and unsafe areas for array placement adjacent to the transmitting antenna are illustrated in figures 3 and 4. Figures 2 to 4 show trend lines defining the safe and unsafe distances between the transmitting antenna and the blasting array for power levels.

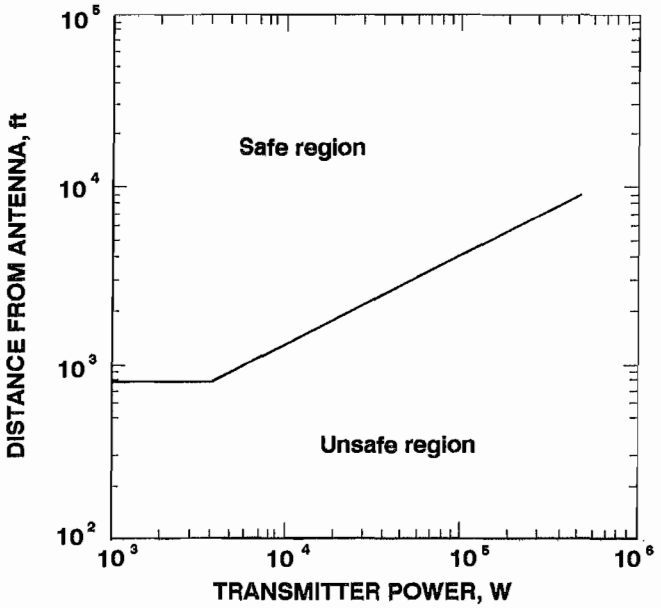


**Figure 2.—Safe and unsafe regions for AM-radio signals.**

Figure 3 illustrates the effects of transmitting at 990 and 2,970 Hz on the safe and unsafe areas for blasting array placement adjacent to the transmitting antenna of the ULF fire warning system. The graphs are very similar, showing little difference between the two frequencies at this ULF range. Therefore, results from tests at the two frequencies are used to generate a single average-value ULF graph (fig. 4). The results of the ULF tests reveal that for a slight frequency change, there is little change in the manner that the EM signal couples and generates current in the blasting array. However, at higher frequencies, the signals couple better to the array. This is illustrated for AM-radio signals in figure 2.

Figure 4 indicates that for 100 W of transmitting power, the safe separation distance between antenna and array must be 9 m (30 ft). When the trend line for the ULF signal that defines safe and unsafe areas is projected to a point at 1,000 W on the horizontal axis, the required separation distance between the edge of the antenna loop and array must be 21 m (70 ft) to maintain a current level of less than 50 mA. In contrast, the AM-radio array must be at least 243 m (800 ft) from a 1,000 W transmitter to maintain the same 50-mA safe level of stray current (fig. 2). A transmission power level of 1,000 W would likely exceed that of any commercial ULF EM warning alarm system.

The results suggest that the higher frequency of the AM-radio signal has a much greater tendency to generate current in an array for similar distances and power levels than does the ULF fire warning signal. This implies that ULF signals are considerably less likely to be a danger to blasting and an appropriately placed transmitting antenna for the ULF EM warning alarm system should not pose a safety threat underground.

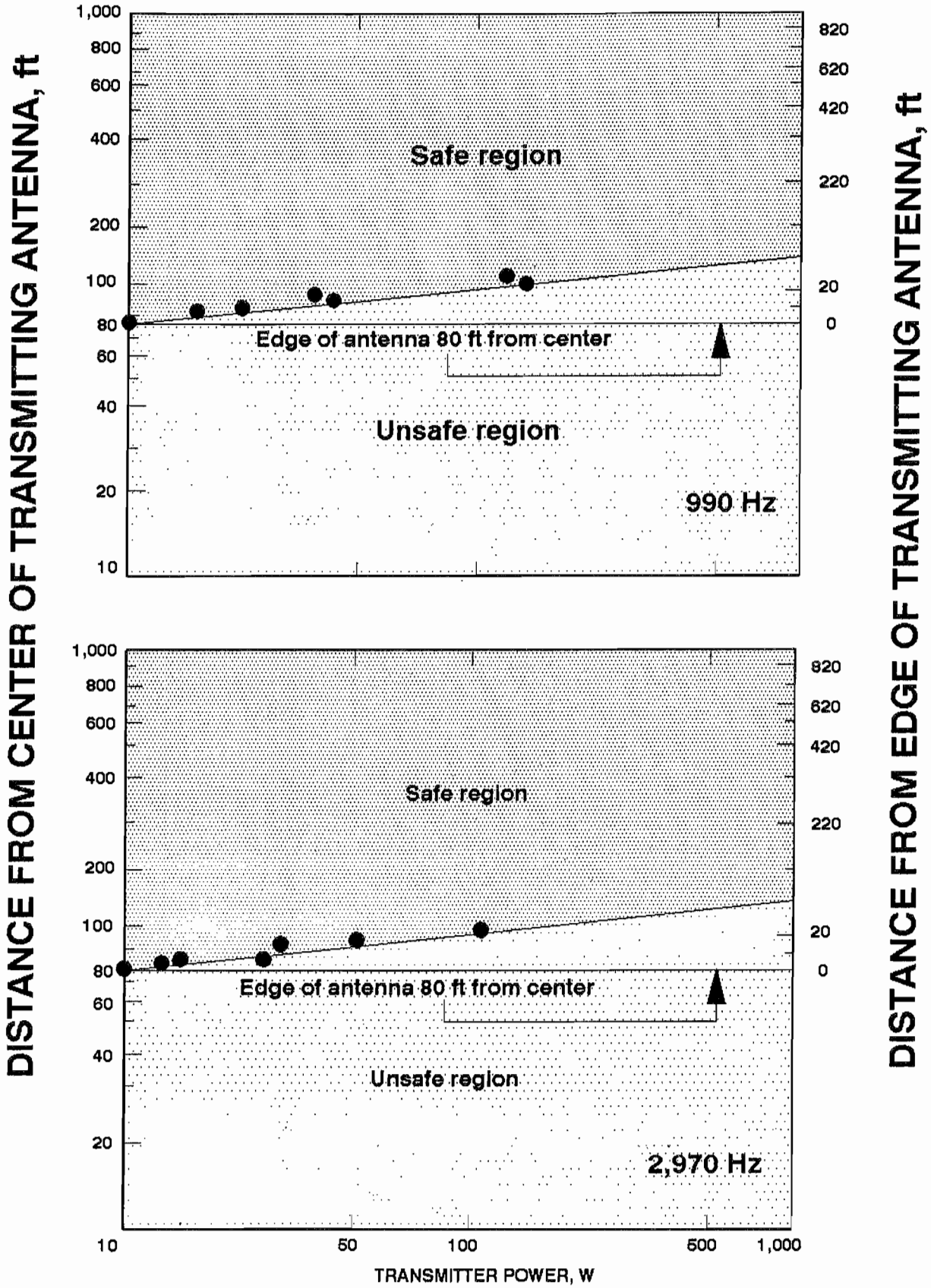


Figure 3.—Safe and unsafe regions for 990- and 2,970-Hz transmitted signals.

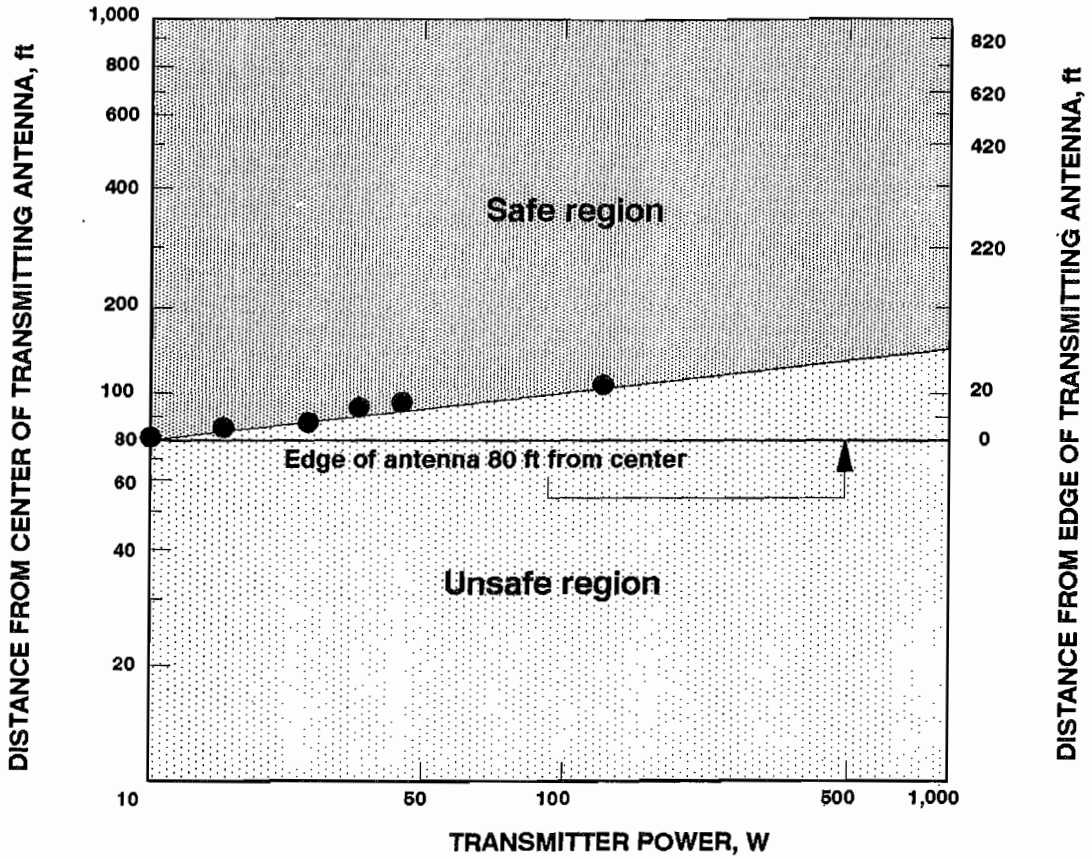


Figure 4.—Average of 990- and 2,970-Hz ULF transmitted signals.

## CONCLUSIONS

Tests were conducted in which a 1-ohm electrical resistor was used to simulate a blasting cap in an array exposed to the EM signal of the ULF fire warning system. Voltage measurements and current levels were established to determine if the warning system would generate a current exceeding the 50-mA maximum safe level established by MSHA in an electric detonator and blasting array.

Results of the tests were used to develop graphs that defined safe and unsafe areas for placement of the blasting array adjacent to the ULF antenna. The results suggested that the EM field of the fire warning system will not cause current levels in the blasting array to exceed the safe level of 50 mA if the blasting array is kept 9 m (30 ft) or more from the 100-W transmitting antenna, or 21 m (70 ft) or more from the 1,000-W transmitting antenna.

IME publication 20 recommends that a blasting array not be placed closer than 243 m (800 ft) from a 1,000-W AM-radio station to ensure that array current levels do not exceed 50 mA (*3*). The results of USBM tests indicate that a ULF signal has less tendency to couple to and generate electrical current in an array than a medium-frequency AM-radio signal.

USBM research indicates that a separation distance of 21 m (70 ft) between the 1,000-W ULF transmitting antenna and blasting array maintains safety and does not adversely interfere with a mining operation. These conditions are valid for transmitting antennas of fire warning systems of similar shape, size, and power levels.

# REFERENCES

1. Hjelmstad, K. E., and W. H. Pomroy. Ultra Low Frequency Electromagnetic Fire Alarm System for Underground Mines. BuMines RI 9377, 1991, 11 pp.

2. Farstad, A. J., and R. F. Kehrman. Electromagnetic Location Systems for Metal/Nonmetal Mines (contract J0166100, Westinghouse Elect. Corp.). BuMines OFR 115-82, 1979, 119 pp.; NTIS PB 82-254525.

3. Institute of Makers of Explosives (IME). Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps). Publ. 20, 1988, p. 13.

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*U.S.G.P.O.; 1993--709-008/80042