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THE EFFECT OF HAND-HELD RADIO OPERATION ON AUDIO DOSIMETERS

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The Effect of Hand-Held Radio Operation on Audio Dosimeters

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Six models of audio dosimeters from five manufacturers were tested to determine the effect of radio frequency (r-f) interference caused by the operation of hand-held radios near the dosimeters on the measured average sound pressure level in a controlled noise field. Exposures were in a reverberant chamber at levels of 36, 80, and 92 dBA to an octave of noise centered at 1 kHz. Two walkie-talkie type radios, one operating at 160 mHz and the other operating at 460 mHz were used to generate the r-f field. The radios were operated on two duty cycles (2 or 3 cycles/min) during the recording period. Reported measures, such as average sound pressure level and peak sound pressure level, were compared for each noise exposure condition with and without operation of the hand-held radio. The results indicate that all makes and models of the dosimeters that were tested gave false readings under some conditions. These values always exceeded the reading in the noise alone control condition and varied by as much as 45 dB above the "true" level. Because each dosimeter behaved differently—including different samples of identical models—it was not possible to develop a correction factor for radio interference. Rather, steps are recommended to help users identify potential r-f contamination on dosimeter performance in the field.

A letter to the Industrial Hygiene Forum by Bohl[1] reported the results of some preliminary experiments involving the effects of radio frequency (r-f) radiation from hand-held walkie-talkies on the exposure reported by several makes of noise dosimeters. It was reported that measures of dose could be inflated by as much as 25 dBA if a small, hand-held radio transceiver was operated near the microphone cable of the dosimeter. Similar observations were made by the second author during routine measures of noise exposure in personnel using radio transceivers. After publication of that report other industrial hygienists reported similar observations.

Noise measuring instruments—both sound-level meters (SLM) and audio dosimeters—are not required by standards of the American National Standards Institute (ANSI) to be resistant to r-f interference from sources commonly found in industry (for example, vehicular ignition systems, arc welders, communication transmitters, and others), according to Earshen.[2] This industrial equipment can produce a sufficient r-f field strength that audio dosimeters used in the immediate vicinity (for example, worn by the same person) of these devices may be affected. Earshen also reported that in the majority of cases, electromagnetic interference will produce readings higher than those resulting from acoustical noise alone. Cook and Huggins[3] reported that a particular make and model of an SLM would indicate off-scale readings when exposed in a controlled r-f field. However, they did not report noise levels in the test environment or address dose accumulation because the test instrument was not a dosimeter.

Occupational Safety and Health Administration (OSHA)[4] has stated that small, light-weight instruments are usually preferred for industrial hygiene monitoring equipment because these instruments are powered by small batteries and have circuits requiring low-power levels. Instruments operating at low-power levels are susceptible to interference from external electromagnetic fields. OSHA in the past has had to modify 400 audio dosimeters. Since that time, new instruments—audio dosimeters, combustible gas meters, air sampling pumps, and air velocity meters—are thoroughly tested.

If measures of noise exposure made with audio dosimeters are contaminated by r-f interference when radio transceivers are operated in the vicinity of the dosimeter, errant readings may occur. The objective of this study was to determine if electromagnetic interference caused by operation of hand-held radio transceivers has an effect on the results reported by commercially available audio dosimeters.

METHODS AND MATERIALS

Sixteen dosimeters commonly used in industrial noise monitoring were evaluated in this study. The sample included six models from five manufacturers: four Quest M15s, four Quest M27s, two Larson–Davis 700s, one Du Pont MK3, one Gen. Rad. 1950A and four Metrosonics DB 301s. With the exception of one Metrosonics dosimeter S/N 1194, none of the dosimeters was fitted with an r-f interference filtering package.

Two hand-held radios that had been in service for more than 1 yr were used. One radio—a Motorola Model H23LCU1144RN, Serial No. 402 AMQ 1619—was supplied by the Union Pacific Railroad. It operated at 4 W of power

TABLE I. Recorded Average Sound Pressure Level vs Correct Average Sound Pressure Level

			Brand	*Quest*	*Quest*	*Quest*	*Quest*	*Quest*	*Quest*
			Model	*M-15*	*M-15*	*M-15*	*M-15*	*M-27*	*M-27*
			S/N	*EV4090061*	*EV4090054*	*EV4090060*	*EV4090059*	*GW7030005*	*GW9010047*
			Microphone	*Attached*	*Attached*	*Attached*	*Attached*	*Attached*	*Attached*
			Criteron	90 dBA	90 dBA	90 dBA	90 dBA	90 dBA	90 dBA
			Threshold	80 dBA	80 dBA	80 dBA	80 dBA	80 dBA	80 dBA
			Exchange Rate	5 dB	5 dB	5 dB	5 dB	5 dB	5 dB
Frequency	*Date*	*Duty*	*Environment*						
	10/2/90	0%	92 dBA				91.6	92	
			Correct Value				92	92	
160 mHz	10/3/90	33%	92 dBA		92.2			119.9	
			Correct Value		92			92	
460 mHz	10/4/90	33%	92 dBA		93.3			92.9	
			Correct Value		92			92	
160 mHz	1/26/91	33%	80 dBA	80	96	84.5		51.9	97.1
			Correct Value	81	81	81	81	81	81
460 mHz	10/5/90	33%	80 dBA		78.5			45.8	
			Correct Value		<80			<80	
460 mHz	10/5/90	33%	80 dBA		78.2				
			Correct Value		<80				
460 mHz	10/19/90	50%	36 dBA	25	61.6	45.8		Lost Data	
			Correct Value	<70	<70	<70			
460 mHz	10/5/90	33%	36 dBA		68.4			45.5	
			Correct Value		<70			<70	

supply to the antenna and a frequency of 160.74 mHz. The second radio, supplied by Monsanto Co., was manufactured by Uniden (Model SPU48OK, Serial No. 93000232). It provided 5 W of power to the antenna, but the frequency was 460 mHz. Both radios were frequency modulated. Tests to determine that the radios met Federal Communications Commission requirements were not conducted. The battery packs for the radios were replaced by an AC-power supply to enable reliable operation for a 2-hr period from AC-line voltage. The transmit switch was controlled by a timer designed and built at the Central Institute for the Deaf (CID). All radios had the power to their speaker interrupted so that no audio signal from the radios could influence the results of the exposure measurement.

All of the dosimeters used in this study had been in routine monitoring service for at least 2 yr. Trained personnel from either CID or Monsanto were the operators.

The dosimeters were calibrated with the manufacturers' calibrators at the start of each day's testing and at the end of these experiments. If any dosimeter did not calibrate, it was not used, and the data were discarded. After it was determined that the dosimeters met the specifications of the manufacturers and of ANSI, the dosimeters were then checked at three frequencies (250, 1000, and 4000 Hz) using a General Radio Omni Cal Sound Level Calibrator Model 1986 (Serial No. 00258).

The room in which the exposures were conducted was an acoustical chamber made reverberant by covering the walls and ceiling with 1-inch plywood that was covered with 1/8-inch thick masonite. The total wall thickness was 5 inches. The interior dimensions of the room were 6 ft by 6 ft. The room was not r-f isolated or electrically grounded. However, all equipment operated in the room was grounded.

The dosimeters were placed in a circle around the base of a ring stand and the microphone cable that was extended upward and draped over a 7-inch ring that was 30 inches above the table (see Figure 1). The radio was placed in the center of the circle of dosimeters with its base 8 inches from the table top. This placed the radio antenna in the center of the microphone cables. On one occasion, the radio was inverted with the tip of the antenna 1 inch from the table.

The radios were operated remotely for the 2-hr exposure period on one of two different time cycles, either 3 cycles/min (6 sec on/14 sec off) or 2 cycles/min (15 sec on/15 sec off). The dosimeters were read at the end of a 2-hr exposure period. Three levels of background noise were used in the exposure chamber. The lowest, 36 dBA, was the ambient sound level in the acoustically reverberant room. An octave band of noise centered at 1 kHz was presented at 80 or 92 dBA for the other exposure conditions. It was generated by a random noise generator (General Radio 1382), filtered by two cascaded

TABLE I. Extended

Quest M-27 GW9010046	*Lar-Dav 700 4086B0773*	*Lar-Dav 700 4086B0774*	*Du Pont MK 3 10362*	*Gen Rad 1954 508305*	*Metrosonics DB301 1193*	*Metrosonics DB301 3165*	*Metrosonics DB301 1191*	*Metrosonics DB301 1194*
Attached	*Attached*	*Attached*	*Attached*	*Attached*	*S/N HL82716*	*S/N HL82753*	*S/N HL82759*	*S/N HL82737* Retrofitted
90 dBA		90 dBA	90 dBA	90 dBA	90 dBA	90 dBA	90 dBA	90 dBA
80 dBA	30 dBA	80 dBA	80 dBA	80 dBA	70 dBA	70 dBA	70 dBA	70 dBA
5 dB	3 dB	5 dB	5 dB	5 dB	5 dB	5 dB	5 dB	5 dB
	92.6	91.6	93.3	93.3	93			
	92	92	92	92	92			
	92.4	92.2	140.8	112.4	92.3			
	92	92	92	92	92			
	92.6	92.9	103.4	114.8	93			
	92	92	92	92	92			
53.9	79.5	79.5	140.7	83.5	79	84.1	82.6	82.3
81	81	81	81	81	81	81	81	81
	80.8	42	79.8	86.2	81.5			
	<80	<80	<80	<80	<80			
	85.8	35.1	90.2	96.1	81.8			
	<80	<80	<80	<80	<80			
	76.4	Lost Data	91	83	83.9	84.5	72.9	
	36		<70	<70	<60	<60	<60	
	79	26.8	65.8	85.2	76.2			
	36	<70	<70	<70	<60			

passive filters (Allison 2BR) amplified (Crown D150A Series II) and delivered by a JBL 2482 driver and a 2343 horn.

RESULTS

Calibration

All dosimeters were within ANSI specifications (ANSI S1.4–1983 and S1.25–1978) when tested with the calibrator from the manufacturer of the equipment. The obtained values, with one exception, fell within plus or minus 1 dB of the specified proper value during the entire series of experiments. On the one occasion, when a dosimeter did not meet calibration, the previously collected data (average sound pressure level and peak sound pressure level response) were discarded.

The test of the dosimeters using the General Radio Omni-Cal gave values at 1 kHz between 107.5 dBA (5 dB below the minimum level) and 115.7 dBA (0.2 dB above the maximum level). Dosimeters tested using this procedure did not indicate appropriate calibration values at all frequencies. The differences were attributed to poor microphone calibrator coupling rather than improper operation because all units operated properly when calibrated with the manufacturer's calibrator and the results of the Omni Cal were consistent from one test to the next.

Exposure Test

Table I gives the average sound pressure level (SPL) dBA value found after 2 hr of exposure. Fifteen dosimeters were set to measure noise by OSHA Standards (90 dB criterion; 80 or 90 dB threshold; 5 dB trading ratio); one Larson–Davis 700 was set according to community noise standards (40 dB threshold; 3 dB trading radio). The reported value is given on the top line of each exposure, and the calculated correct exposure value is given on the second line.

To verify the procedure, a special test was made at an ambient exposure level of 82 dBA without any radio transmission with one of the Quest M–27 dosimeters. An exposure of 82 dBA was reported (the correct value). This test is not shown in Table I.

Exposures to a sound field of 92 dBA with no radio transmission (top row of Table I) gave results from +0.4 to +1.3 dB of the proper value. These values fall within the provisions of calibrated Type 2 dosimeters. However, when a 160 mHz radio signal was broadcast at a 33% duty cycle, results were never lower than the ambient noise and ranged to 140.8 dBA—48.8 dB greater than the correct value (Row 2, Du Pont MK3). The three high values were 119.9, 140.8, and 112.4 dBA. When the 460 mHz radio was used under the same

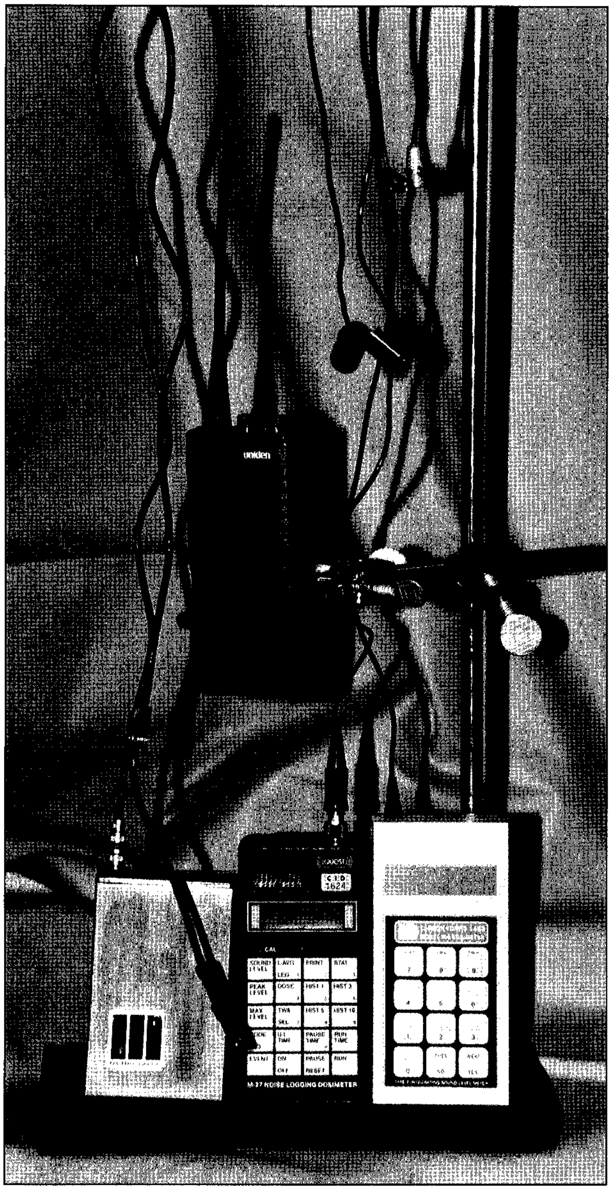

FIGURE 1. The configuration of the audio dosimeters around the the hand-held radio

conditions, the high values were 103.4 and 114.8 dBA. These values are 11 to 23 dB higher than the correct values.

When the ambient noise level in the exposure chamber was 80 dBA and the duty cycle was at 33%—that is, 3 operations/min and the radio operating at 160 mHz—average SPLs ranged from the correct values to excursions of 15 to 60 dB. One Quest M15 ranged from 1 to 15 dBA high. Similar results were found for the 460-mHz radio. A second test was made using the same 460-mHz radio but placed upside down in the holder with the tip of the antenna 1 inch from the surface of the table. Differences in exposure values were found of 6 dBA in the Larson–Davis dosimeter. Higher differences were found in other brands.

In the 36-dB environment, average SPLs as high as 91 dBA were reported. In fact some dosimeters results indicated that costly corrective action was needed when the average sound pressure level was 36 dBA.

All sound pressure levels obtained during these tests indicated higher than the actual ambient exposure conditions (36 to 92 dBA) when a radio transceiver was used. This occurred with radios operating at 160 and 460 mHz. These dosimeters gave exposure values close to the expected values when the audio signal was not contaminated with radio transmissions.

Other Metrics

All of the dosimeters had the ability to report other metrics; for example, sound of exposure levels (SEL), high values, and so on. The experiment conducted in the 36 dBA environment with the 460-mHz radio operating gave results ranging from a low of 74.2 dBA to a high of 114 dBA. The mean value was 95 dBA and the median values were 82.5 and 83.6 dBA. The correct value should have been at least 10 dB (typically 20) below the threshold of measurement dependent on the make and model of the dosimeters.

The difference between equivalent continuous levels and those obtained with a 5 dB trading ratio (LOSHA) values was examined to find if other metrics could give some information as to the source of the interference. Two dosimeters from the same manufacturer with consecutive serial numbers (Columns 7 and 8 in Table I) were exposed to the same conditions. The data from the dosimeter with the 30 dB threshold were more severely affected than those from the dosimeter with the 80 dB threshold. In general, the lower the threshold is set to accumulate noise exposure data, the higher the excursion of the reported value from the true value. This finding suggests that the effect of r-f is greatest when the current flow from the microphone is the lowest.

Measures of peak SPLs for each type of dosimeter—Quest, Larson–Davis, and Du Pont—that was able to capture those data are summarized in Table II. In all cases the true peak value would not have exceeded 111 dB. This was determined by measuring the noise field with a B&K Model 2231 sound-level meter while the radios were turned off. Peak sound pressure level values recorded by the dosimeters ranged from 94.8 to 140 dBA. A true noise event such as closing the chamber door would not have exceeded the lowest measured value, 94.8 dB. Therefore, values higher then 111 dB must be considered to arise from r-f interference or some other unknown spurious signal.

DISCUSSION

Although the results are complex, several deductions can be made. The data indicate that all brands of dosimeters tested gave inflated results when radio transceivers were used in the immediate vicinity of the dosimeter (within 1 ft). The degree of inflation was not predictable from the description of the dosimeter; that is, make and model, ambient test conditions, or operation of the radio transceiver. Generally, the inflation ranged between 2 and 10 dB. This inflation could indicate the

TABLE II. Recorded Peak Sound Pressure Level vs Correct Peak Sound Pressure Level

			Brand Model S/N	Quest M-15 EV4090054	Quest M-27 GW7030005	Lar-Dav 700 4086B0773	Du Pont MK 3 10362
			Microphone	*Attached*	*Attached*	*Attached*	*Attached*
Frequency	*Date*	*Duty*	*Environment*				
	10/2/90	0%	92 dBA		111.7	120	
			Correct Value		111	111	
160 mHz	10/3/90	33%	92 dBA	110.2	145.1	113	0FL
			Correct Value	111	111	111	111
460 mHz	10/4/90	33%	92 dBA		108	133.5	
			Correct Value		111	111	
160 mHz	1/26/91	33%	80 dBA	124.5	105.7	112	0FL
			Correct Value	111	111	111	111
460 mHz	10/5/90	33%	80 dBA	96.3	133.8	134.5	
			Correct Value	111	111	111	
460 mHz	10/5/90	33%	80 dBA	94.8	102	141	
			Correct Value	111	111	111	
460 mHz	10/19/90	50%	36 dBA	96.3	98.2	133.5	
			Correct Value	N.V.	N.V.	N.V.	
460 mHz	10/5/90	33%	36 dBA	112	129	136.5	112.4
			Correct Value	N.V.	N.V.	N.V.	N.V.

need for costly corrective action to protect employees when, in fact, the true exposure values are below compliance levels. It is not possible to predict the response of a dosimeter when a radio transceiver is in use. The only way of determining whether or not there is an effect is to use the dosimeter for short-term duration with the radio and check the effect on the dosimeter.

The r-f interference was roughly inversely proportional to the measured noise level; that is, measurements made in low noise conditions were more affected than those made in high noise conditions. This was most likely due to the current flow in the microphone cable. In a low noise condition, the current flow in the microphone cable is very low, and the interference from an r-f signal greatly increases that current flow, which causes the dosimeter to record a high noise level.

It has been called to the attention of the authors that one manufacturer of audio dosimeters is now affixing a label to their dosimeters indicating r-f may interfere with the results obtained when sampling.

CONCLUSIONS

All tested audio dosimeters were susceptible to r-f interference when used within 1 ft of radios transmitting at frequencies examined in this paper. Caution should be used whenever audio dosimeters are used in close proximity to any r-f generator. Dosimeters will include the transients from the operation of the radio into the reported dose for an employee exposure, thus giving a higher than true TWA exposure value.

RECOMMENDATIONS

There are three recommendations. One is that before any noise dose measurement is made with an audio dosimeter when the subject must use a radio, there should be a test prior to the exposure measurement in which the radio is operated several times very rapidly and response of the dosimeter indicated before the start of exposure measurement. The second recommendation is to adhere to the suggestion of Earshen,[(2)] as follows:

> when interference is suspected, the reading of the instrument in the suspected location should be noted as the instrument is normally employed. The measurement should then be repeated under identical conditions but this time with the manufacturer's recommended calibrator covering the microphone. A substantial reduction should be observed (at least 10 dB); if not, interference must be suspected and further efforts to locate the source (or shield the instrument) must be made.

The third recommendation is that a recognized standards setting group develop a standard for determining susceptibility of audio dosimeters to r-f interference. This should include the extent of interference and a method of field evaluation. Field evaluation means remote from a laboratory and the procedures are not difficult and time-consuming. These requirements are based on the fact that dosimeters are used for legal and regulatory enforcement actions. (Note: As of May 1992 ANSI.S1 has established a working group to write a standard concerning r-f interference.)

The results of this investigation clearly indicate that the current set of instruments available to industry are not free from the problems of interference by radio signals. The effect seen is an elevation of the indicated noise exposure in all cases.

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