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Magnetic Fields From Steel-Belted Radial Tires: Implications for Epidemiologic Studies

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Magnetic fields emanate from radial tires due to the presence of reinforcing belts which are made of magnetized steel wire. When these tires spin, they generate alternating magnetic fields of extremely low frequency (ELF), usually below 20 Hz. The fundamental frequency of these fields is determined by tire rotation rate and has a sinusoidal waveform with a high harmonic content. The static field of radial tires can exceed 500 μT at the tread, and the tire-generated alternating fields can exceed 2.0 μT at seat level in the passenger compartment of vehicles. Degaussing the tires reduces both the static and alternating fields to low levels, but the fields increase gradually over time after degaussing. The tire-generated fields are below the frequencies detected by most of the magnetic field meters used in previous studies of power frequency magnetic field health effects. If these fields are biologically active, failure to detect them could compromise exposure assessments associated with epidemiologic studies. Bioelectromagnetics 20:440–445, 1999. © 1999 Wiley-Liss, Inc.

Key words: steel-belted radial tires; tire-generated alternating magnetic fields; magnetic field exposure assessment; degaussing; automobile tires

INTRODUCTION

Vedholm and Hamnerius [1997] reported that steel-belted radial tires were magnetic and that they generate alternating magnetic fields in the passenger compartments of cars. We studied the nature of the static magnetic fields of these tires, the magnetic fields generated when they spin, and the feasibility of eliminating them. We also studied the ability of a gaussmeter used in a number of epidemiologic studies of magnetic field health effects to sense sub-ELF magnetic fields and considered the consequences of failure to detect them on study outcomes.

METHODS

Using a simple compass, a fluxgate magnetometer (Walker FGM-301), and a simple magnetometer (R.B. Annis Company, Magnetic Equipment), the static magnetic fields of new radial tires, tires in use on cars, and discarded tires were studied. The spatial distribution of the static magnetic field across the tire tread surface was examined. The field pattern on a cut section of a radial tire segment was visualized by using iron filings on white paper held against the cut section of the tire segment.

The static magnetic fields of radial tires were examined using the fluxgate probe clamped into a position that minimized the influence of the earth's magnetic field. The alternating magnetic fields generated by spinning tires were examined at tire-balancing machines, on a jacked up car with the tire spun manually, and in moving cars. Fields were measured by using an Emdex II meter (Entertech Consultants), an FW Bell meter (FW Bell model 4080; FW Bell, Orlando, FL), and the fluxgate meter connected to a portable oscilloscope (Tektronix 222 Digital Storage Oscilloscope) and a portable computer (Toshiba Satellite T2120CT, model PA1198UX loaded with Metratek Waveform Manager, version 2 for Microsoft Windows 3.1). Magnetic flux density time-series data were acquired and transformed into the frequency domain by using a fast Fourier transform (FFT) algorithm in the Waveform Manager software. Readings were also made in a moving car with a Holaday Industries Model HI-3627 orthogonal ELF magnetic field meter.

Tires on a jacked up car were degaussed by using a hand-held magnetic tape degausser (Geneva Audio/Video Tape Eraser, mod. PF 211). The degausser was

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held near the tread of a tire spun manually, and gradually moved away from the tire over a 15 second period. Tire fields were studied before and after degaussing.

The potential implications of tire-generated fields on previous EMF epidemiologic study results were considered.

RESULTS

The needle of a compass was deflected when held near the tread of radial tires. The north-pointing needle was attracted and repulsed at various positions on the tire tread less than an inch apart. With the fluxgate probe clamped in a position that minimized the earth's magnetic field reading, a radial tire tread moved against the probe gave positive and negative readings over the 200 μT (2000 mG) detection limit of the instrument, again over short distances along the tread. Some tires had static magnetic fields which exceeded the 500 μT (5000 mG) detection limit of another magnetometer (R. B. Annis Company). All radial tires examined were magnetic, and every tire had its own unique magnetic field pattern. Certain brands of tire had stronger static fields than others. Moving the probe away from the tire caused the indicated static magnetic fields to drop off dramatically with distance (Fig. 1). Figure 2 shows a photo of the magnetic field pattern demonstrated by iron filings on white paper held against the cut edge of the tire segment. From the tire segment examined, we calculated that the tire contained about 1,463 meters (4,800 feet) of wire 0.238 mm (0.009 inches) in diameter.

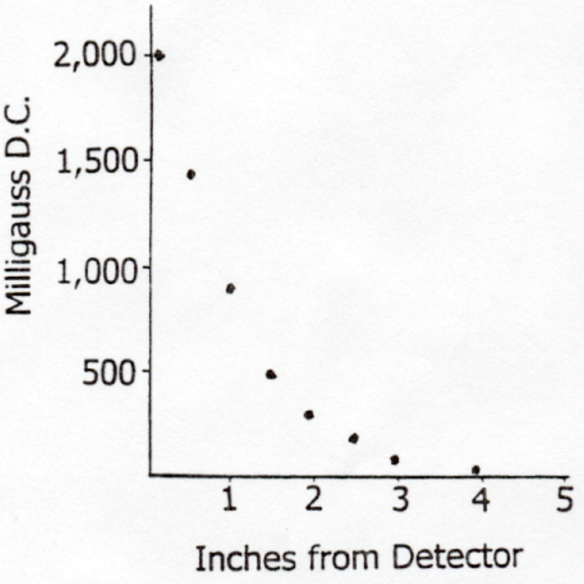

Fig. 1. DC magnetic field by distance from detector of fluxgate magnetometer (Walker FGM-301) of a steel-belted radial tire segment (1 in = 2.54 cm, 1 mG = 0.1 μT).

The alternating fields generated by a spinning tire were as high as 2.0 μT in the car, and the observed fundamental frequency could be accurately predicted by tire rotation rate. The field strengths in the passenger compartment of a moving car varied from 0.2 μT to 2.0 μT, with the highest fields on the floor of the front seat near the doors and on the back seat near the doors. The lowest fields were found in the center of the car and near the roof. In two cars tested, the fields were roughly sinusoidal; frequencies were about 6 Hz at 48.3 km/h (30 mi/h) and 12 Hz at 96.6 km/h (60 mi/h) with high harmonic content. Although frequency increased with tire rotational speed, the magnetic field intensity remained nearly constant at all speeds. Figure 3 shows the waveforms and Figure 4 the Fourier transformations obtained at 48.3 km/h (30 mi/h). The positive peak measured 3.64 μT, the negative peak −3.12 μT, peak to peak 6.76 μT; the frequency was 6.21 Hz, and the AC R.M.S field was 1.93 μT. Magnetic field intensity in the passenger compartment decreased as distance from the tires increased. At the tire balancing machines, magnetic field intensity decreased rapidly with distance from the tread of a spinning tire. These patterns have been recently confirmed by others [Jacobs et al., 1998]. For example, they recorded a magnetic field of 30.4 μT at 10 cm from a spinning tire which decreased to 0.74 μT at 70 cm and to 0.069 μT at 160 cm.

In the car, the Emdex II meter read 0.2 μT or below in the same place on the seat when the fluxgate probe detected 1.9 μT. At a commercial tire balancing machine, fields above 1.0 μT were measured 0.91 m (3 ft) from a spinning tire. At the same position and at the same time an Emdex II meter read 0.13 μT. Using a common loop magnetic field sensor (Holaday Industries Model HI 3627 orthogonal ELF field meter), an apparent relationship between speed (and hence the frequency of the magnetic field) and magnetic field intensity is seen, which is not seen when the fluxgate probe is used (Fig. 5).

After degaussing one tire on a car, the static magnetic field detectable on that tire and the alternating magnetic field measured in the passenger compartment near that tire with the car moving were both reduced to low levels. The alternating field in the car was reduced from 2.0 μT to 0.2 μT. Both field intensities have increased gradually in the 6 months since degaussing with the alternating magnetic fields reaching 0.6 μT in the car.

Fig. 2. Photograph of iron filings on white paper against a cut radial tire segment.

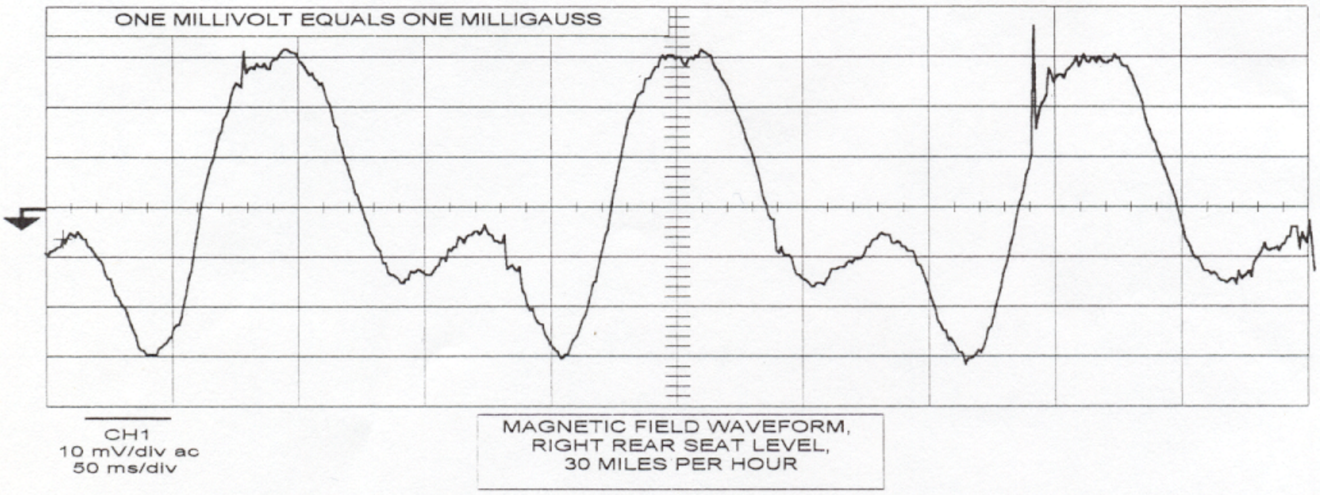

Fig. 3. Waveform obtained at seat level, rear door at 30 mi/h (48.3 km/h) (1 mG = 0.1 μT).

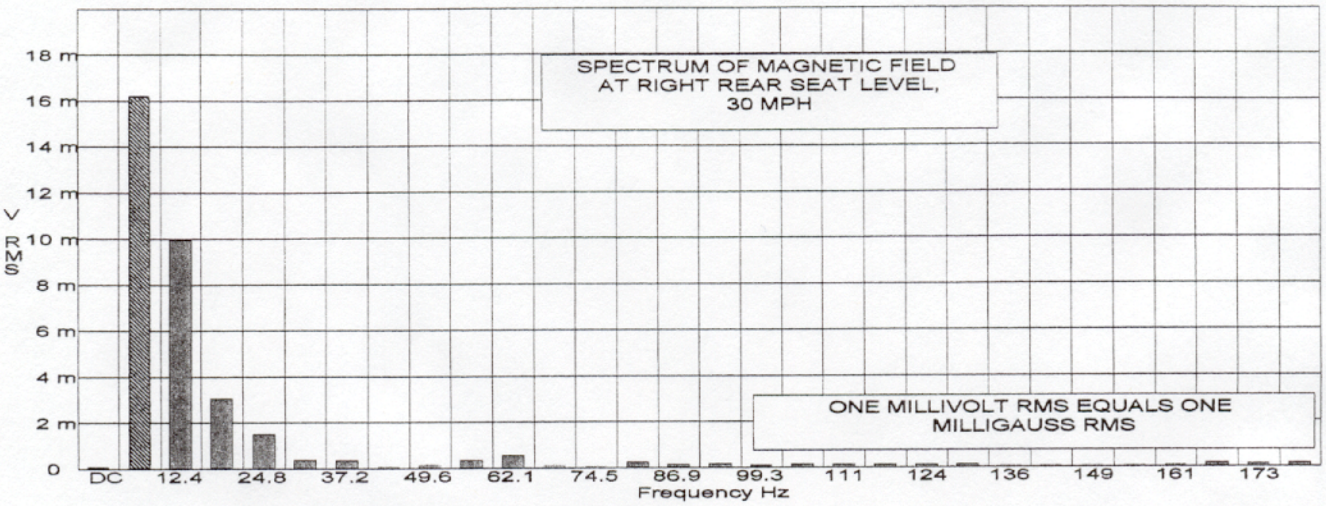

Fig. 4. Fast Fourier transformation of waveform in Figure 3 (1 mG = 0.1 μT).

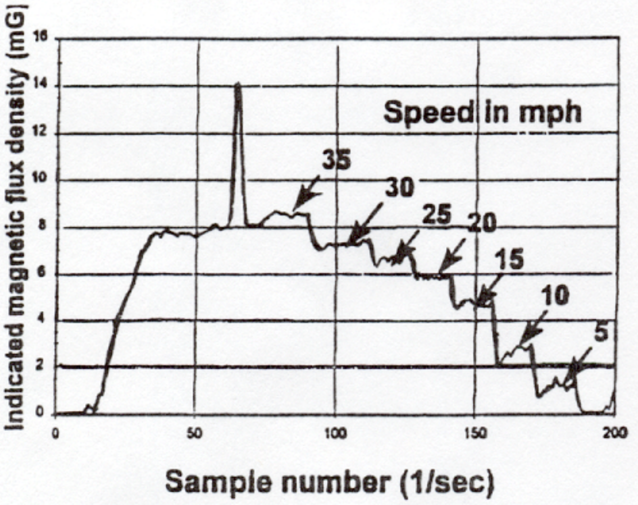

Fig. 5. Magnetic flux density by speed by using a common loop magnetic field sensor (1 mG = 0.1 μT).

DISCUSSION

We think that magnetism is induced in the steel reinforcing wire during its manufacture. Beginning as a high carbon steel rod, it is drawn through successively finer dies and then braided and woven into the belts used to reinforce radial tires. The small area pattern of magnetism seen in the belts is probably best explained by the juxtaposition of the magnetic domains of the single strands of wire which make up the belt, with reinforcement or cancellation of fields of neighboring wires. The peak amplitude of the alternating magnetic field has a constant value, equal to the summed static field strength of the tire dipoles, and is independent of the tire rotational speed and field frequency.

Since the generated magnetic fields drop off quickly with distance, vehicle geometry in reference to the tires will be a major factor in determining exposure of vehicle occupants. In the passenger compartment, fields are highest in places closest to the tires. In the two cars examined, fields are highest on the floor of the front seat near the doors and on the back seat near the doors. Passengers sitting near the doors on the rear seat will have higher exposures than passengers sitting in the middle of the rear seat by virtue of their distance from the rear tires. On a bus, seats directly over the rear wheels present the potential for higher exposures. Drivers in trucks with the driver's seat directly over the front tires will have higher exposures than drivers in trucks with the front wheels well forward of the driver's seat. The highest exposure of a left-seated passenger car driver will be to the left foot and lower leg.

If these tire-generated fields have biological impacts similar to those of the power frequencies, the ELF magnetic field exposure assessments done in the large epidemiologic utility worker studies [Sahl et al., 1993; Theriault et al., 1994; Savitz and Loomis, 1995] will have had their risk estimates compromised by case/control misclassification. There are few studies of EMFs at these frequencies, but fields below 1.0 Hz have been shown to affect human reaction time [Friedman, 1967]. All of the measurement-based epidemiologic studies used magnetic field meters designed to measure the power frequencies (50 and 60 Hz), but reject frequencies below 35 Hz in order not to register artifacts caused by moving the meter in the earth's static magnetic field.

The Emdex-type meters reject magnetic fields below 35 Hertz (Hz) very effectively. This accounts for their inability to detect the tire-generated fields that are usually below 20 Hz. The manual which accompanies the Emdex II devotes a page to "Rejection of the Earth's Magnetic Fields" and specifies signal rejection capabilities of 1:1,000 at 10 Hz and 1:10,000,000 at 2 Hz. Similarly, the apparent relationship between speed and magnetic field strength seen in Figure 5 is due to the frequency response of the HI 3627 loop sensor, which is designed to reduce the sensitivity of the meter at the lower ELF and sub-ELF frequencies. The magnetic field readings that decrease with decreasing vehicle speeds (and hence decreasing magnetic field frequency) are the result of a design feature found in most meters (including the HI 3627) that causes the sensitivity of the measuring device to decrease as the frequency becomes lower to avoid effects of motion in the earth's magnetic field.

If the various magnetic field exposure groups in these studies were to have their mean exposures increased by a constant amount due to tire-generated fields, the 50 or 60 Hz control or reference groups will have the largest percentage increase in magnetic field and may not be a suitable baseline for comparison. Some of the job titles in the control group in the occupational studies will move into the exposed categories, and depending on where exposure cut-points are set, some job titles may move from exposed group to controls. The failure to measure tire-generated fields may also explain why higher (0.3 μT [3 mG] vs. 0.2 μT [2 mG]) magnetic field exposure cut points in exposure-based epidemiologic studies are associated with increased odds ratios [Wartenburg and Savitz, 1993; Linet et al., 1997]. The higher exposure cut points may maximize the power frequency contribution to exposure in the case group. It is quite possible that more complete ELF exposure assessment in these studies may refine and increase calculated risks, since exposure mis-classification will usually bias risks toward the null.

Since average residential magnetic fields are generally well below those measured in electrical occupational settings, the tire-associated fields may be even more important to measure in residential or non-occupational studies. The range of average 24 hour magnetic field exposures of controls in one of the residential childhood leukemia studies was 0.00–0.067 μT (0.00–0.67 mG) [London et al., 1991]. In fact, the highest exposure group had an average 24 hour residential exposure of 0.115 μT (1.15 mG). These values could easily be doubled by traveling one hour a day in the back seat of many cars. If tire fields are considered, personal exposure measurement with meters which capture fields below 35 Hz will give a very different picture of exposure than strictly residential measurement. Again, exposure mis-classification will usually bias risks toward the null.

The potential public health implications of tire-generated fields, if any, could be addressed much more simply than power-frequency fields. New non-magnetic steel-belted radial tires could be manufactured, and existing tires can be demagnetized.

Although occupational solid tumors have average latencies over 20 years, an examination of tumor registry data for changes in cancer patterns for drivers and others exposed to these fields might be revealing. Since a driver's feet have high exposures compared to other parts the body, a change in the topical distribution of malignant melanomas might be expected, with increases seen on the feet and legs below the knee, especially on the left foot in the United States and in other places with left-seated drivers. Since these fields also overlap brain-wave frequencies to a great extent, it could be interesting to study how these fields affect driving performance and other brain functions.

The fact that tire-generated fields were not noticed for the nearly 20 years of active epidemiologic research into EMF health effects is surprising, but is probably due to the focus of research on the power frequencies. It is possible that other important human EMF exposures are hidden in other parts of the EMF spectrum.

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