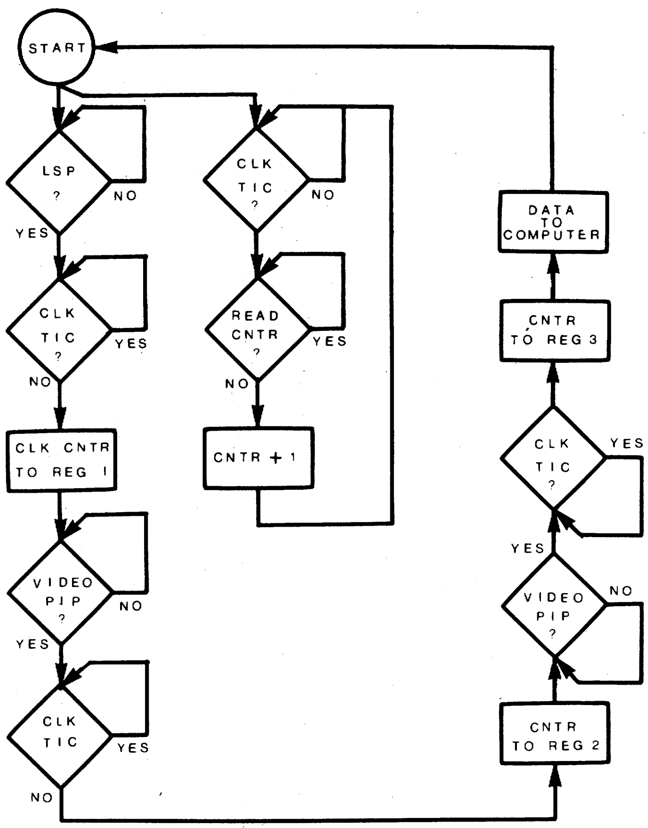


Fig. 4. Digitizer flow diagram.

used. Resolution could be increased using a different lens on the camera so that the image of interest fills most of the raster. However, care must be taken to ensure that the horizontal deflection is linear (in time) over the full line scan in order to minimize spatial distortion. This is usual in more expensive cameras, but is not the case for the inexpensive unit used here. Thus a small portion of the linewidth is used to improve the effective spatial linearity of the system.

## V. Digitizer Design Pitfalls

In designing the digitizer, it is important that a trigger pulse does not initiate a counter read cycle during a clock pulse or immediately thereafter when the clock count may be rippling through the counter.. Although such coincidences will normally be rare, such an occurrence will cause ambiguous data. To eliminate such possibilities, the clock pulse is used to lock out the trigger and store it until the clock pulse has terminated plus a finite delay time. To achieve the high clock frequency required for resolution, a counter with "look ahead" gating and low (80 ns typical) propagation time is used. In the same way and for the same reasons, the clock pulse must be locked out (but not lost) during a counter read cycle.

## VI. Conclusion

For those interested in such topics, the cost of parts for the digitizer was $400.00, and for the computer interface, $50.00, bringing the total system cost, including camera and monitor at $350.00, but excluding processor and recorder, to $800.00. It should also be noted that the digitizer is not committed to this use alone, but is designed as a computer peripheral for any use where up to three separate channels of high-speed time keeping functions are required. It can also be used to perform three channels of computer interrupt with each channel having its own analog level detection.

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# Addendum and Corrections to "Propagation of Plane Waves Through Two Parallel Dielectric Sheets"

CLAUDE M. WEIL

***Abstract*—Additional data, needed to complete the problem solution and omitted in the above communication,[1] are presented showing actual maximum and minimum $/E/^2$ values for the standing waves which exist between the two sheets. Two corrections to the original work are also given.**

## Addendum

In an earlier communication by this author,[1] an analytical study was presented of the perturbations to a plane wave field created by two parallel dielectric sheets. The purpose of this study was to demonstrate, using this simplified model, that animal restrainers made of dielectric materials can significantly compound the densitometric problems associated with free-field exposures of experimental animals in microwave bioeffects research. The data presented were limited to plots of the square of the standing wave ratio $|E_{max}/E_{min}|^2$ against normalized sheet thickness or dielectric permittivity, where $E_{max}$ and $E_{min}$ represent maximum and minimum $E$-field values in the region between the two sheets. Seaman [1] has recently pointed out that such data could have been obtained

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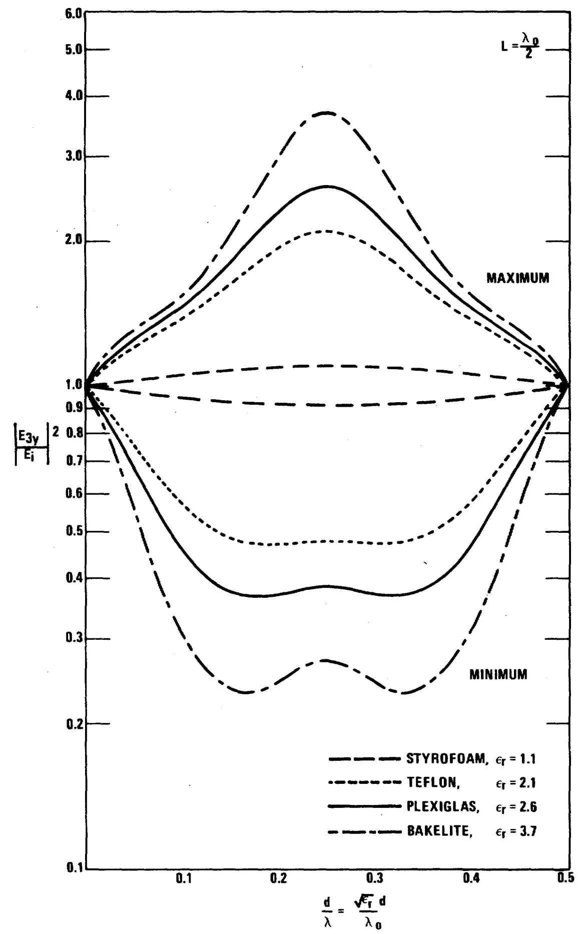


Fig. 1. Maximum and minimum values of normalized field strength between dielectric sheets as a function of normalized sheet thickness.

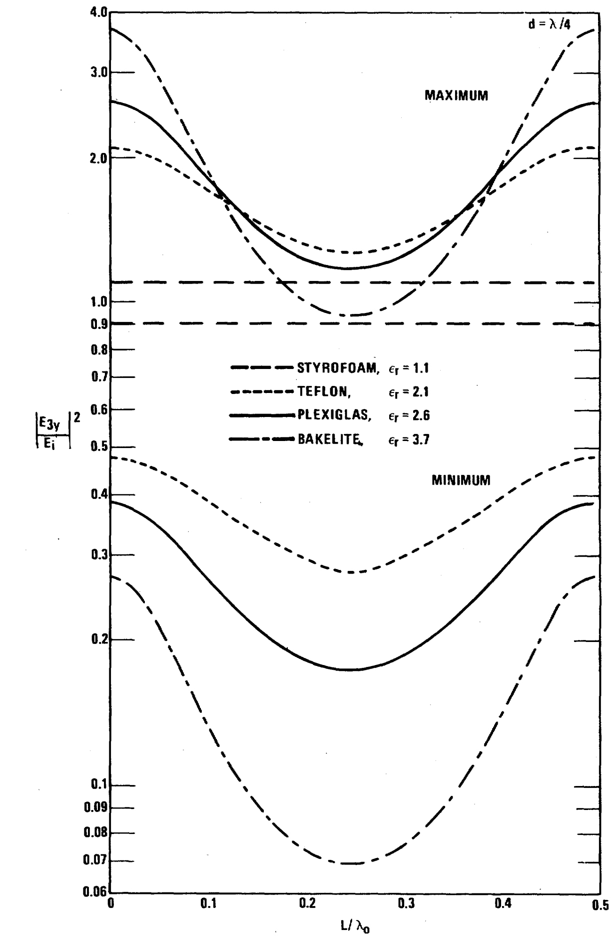


Fig. 2. Maximum and minimum values of normalized field strength as a function of normalized sheet separation.

in a simpler and more direct manner, but that an analysis of the type presented in the original communication[1] is still needed in order to completely define the actual maximum and minimum values of $/E/^2$, rather than just their ratio. From a densitometric point of view, it is obviously most desirable to know the absolute value of $|E_{max}|^2$ or $|E_{min}|^2$ as well as its ratio, but such data were regrettably omitted from the original paper. Figs. 1 and 2 provide the additional data needed; in Fig. 1, maximum and minimum values of $|E_3|^2$, normalized with respect to the incident field $E_i^2$, are plotted against the normalized dielectric sheet thickness, $d/\lambda$, for a fixed separation distance between sheets of a half-wavelength ($L = \lambda_0/2$). Fig. 2 shows the same parameters plotted against separation distance between sheets, $L$, for a fixed quarter-wave sheet thickness ($d = \lambda/4$). The data shown in Figs. 1 and 2 were derived directly from (13), as corrected (see following section).

Seaman [1] has emphasized that the standing wave ratio for the $E$-fields between the sheets is influenced only by the second or "downstream" dielectric sheet. However, the data in Figs. 1 and 2 demonstrate that the absolute $/E/^2$ levels for the standing wave setup between the two sheets are very much affected by the presence of the first sheet and are dependent on sheet thickness, $d$, and separation distance between sheets, $L$.

## CORRECTIONS

There are two typographical errors which appeared in the original paper.[1] A column in the left-side matrix of (11) was unfortunately omitted. The corrected version should read as follows:

$$\begin{bmatrix} 1+n & 1-n & 0 & 0 & 0 & 0 & 0 \\ \exp(-jkd) & \exp(jkd) & -1 & -1 & 0 & 0 & 0 \\ n\exp(-jkd) & -n\exp(jkd) & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -\exp(-jk_0L) & -\exp(jk_0L) & 1 & 1 & 0 \\ 0 & 0 & -\exp(-jk_0L) & \exp(jk_0L) & n & -n & 0 \\ 0 & 0 & 0 & 0 & \exp(-jkd) & \exp(jkd) & -1 \\ 0 & 0 & 0 & 0 & n\exp(-jkd) & -n\exp(jkd) & -1 \end{bmatrix} \begin{bmatrix} E_2^+ \\ E_2^- \\ E_3^+ \\ E_3^- \\ E_4^+ \\ E_4^- \\ E_5^+ \end{bmatrix} = \begin{bmatrix} 2E_i \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Equation (13) should be corrected as follows:

$$\left|\frac{E_{3y}}{E_i}\right|^2 = \frac{\begin{array}{c} 4n^2[\cos k_0(z-d)\cos kd + n\sin k_0(z-d)\sin kd]^2 \\ +4[\cos k_0(z-d)\sin kd - n\sin k_0(z-d)\cos kd]^2 \end{array}}{4n^2\cos^2 2kd + (1+n^2)^2\sin^2 2kd}.$$

ACKNOWLEDGMENT

The author wishes to thank M. C. Agrawal of the University of Roorkee, India, for bringing the error in (11)[1] to my attention.

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## Perturbation Effect of Animal Restraining Materials on Microwave Exposure

JAMES C. LIN, HOWARD I. BASSEN, AND CHUAN-LIN WU

*Abstract*—**The perturbation introduced by low-loss dielectric materials in a microwave field was assessed through experiment and analysis. The model chosen was that of a plane wave incident at an arbitrary angle upon a rectangular Plexiglas slab of finite width and thickness. It is shown that the perturbation produced by a slab parallel to the direction of propagation is at least as great as the normal incident case. Good agreement between theory and experiment was obtained.**

### I. INTRODUCTION

In most laboratory experiments conducted to assess the biological effects of microwave radiation, it is necessary to use low-loss dielectric materials such as Plexiglas and glass for restraining animals or holding tissue samples under irradiation. It is well known that these materials, although low-loss, have small dielectric constants ($\epsilon_r$ less than 6) which scatter the incident radiation. Since recent emphasis on the biological effects and health hazards of microwave radiation has been on the quantitative relationships between observed biological effects and the physical variables of microwave radiation, it is important to analyze the nature of the scattered fields and determine the degree of complication introduced by the restrainers.

Some related studies have appeared in recent years. For instance, a theoretical study of the standing wave patterns created between two parallel sheets of Plexiglas when a plane wave impinges normally on the dielectric showed that under the worst conditions there could be as much as a 6 to 1 variation in the power density between the sheets [1].

In this study, the scattered fields produced by rectangular Plexiglas slabs of the thickness and width commonly found in animal restrainers used in research on microwave biological effects were investigated through theory and experiments. In the theoretical analysis, the incident microwave radiation was assumed to be a uniform plane wave and the slabs were taken to be infinitely long. The method of solution closely followed one previously developed [2] in which a set of linear equations was obtained for the induced fields inside the slab. These equations were solved using a large digital computer to give the field outside the Plexiglas slab.

A good approximation of a plane wave field was generated in a high-performance anechoic chamber for the experimental portion of this study. A Plexiglas sheet of 6 mm × 0.13 m × 1.21 m was used to simulate the basic components of an animal holder (Fig. 1). The 1.21-m length was chosen to approximate an infinitely long slab. The measurements were made along the middle of the slab. This model gives first order information regarding the scattered field behavior in many exposure protocols.

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### II. EXPERIMENT

#### *A. Experimental System*

A truncated pyramidal horn (0.13 m × 0.17 m aperture) was utilized in conjunction with a 200-W TWT amplifier and leveled 2450-MHz source to generate a good approximation of a plane wave in the 2 m × 1 m × 1 m quiet zone of a high-performance anechoic chamber (9 m × 3.6 m × 3.6 m). In this zone, at a distance of 3.9 m from the antenna, a miniature electric field probe was placed so that it directly intersected the propagation axis of the horn antenna. The probe's handle was placed normal to the electric field vector and the Poynting vector, as were the electrical wires from the probe's detector output. A plastic arm and foam pedestal provided a minimally scattering support structure for the probe. A chain driven cart, made of epoxy–Fiberglas sheets, was mounted on rails which run down the axis of the chamber. This cart was used to transport the Plexiglas test specimen past the stationary probe with cart distance data accurately provided by means of a gear system and shaft encoder with a total uncertainty of 2 mm along the 7-m length of travel.

Standing waves in the quiet zone of the chamber were less than ± 0.25 dB at 2450 MHz. The cart's front and top surfaces were covered with microwave absorber to maintain minimal perturbation to the plane wave (less than ± 0.25 dB). The chamber and cart are shown in Fig. 2 with the probe and Plexiglas specimen in position.

#### *B. Miniature Electric Field Probe*

An array of three orthogonal dipoles, each 2.5 mm in length, was used to monitor the electric field [3]. A beam-lead, zero-bias Schottky diode was mounted across the center gap of each dipole. High-resistance, thin-film leads carried the detected voltage down the 30-cm handle of the probe where thin copper wires were then attached. A differential preamplifier was connected to the wires and the amplified signal was fed out of the chamber on coaxial cables. Appropriate amplifier shielding and microwave absorber were used to minimize perturbation of the fields near the probe and to eliminate RFI effects in the amplifier circuitry. The performance of the probe was previously evaluated so that the linearity of the square law detector and a true dipole antenna pattern were known to exist for each axis. The small size of the antennas and the high-impedance leads were important properties of the probe, since any mutual reflections between the probe and test specimen would yield faulty data.

#### *C. Experimental Results*

Two experiments were performed using a Plexiglas sheet (0.6 cm × 13 cm × 1.21 m) mounted on a 30 cm × 30 cm × 0.6 cm Plexiglas base. The base was shielded from the incident fields by the absorber material on the front of the cart which extended 30 cm above the top of the cart. The geometric center of the Plexiglas specimen was aligned with the axis of propagation of the horn antenna. Data were taken for two orientations of the sheet. In the first case, the sheet's sur-