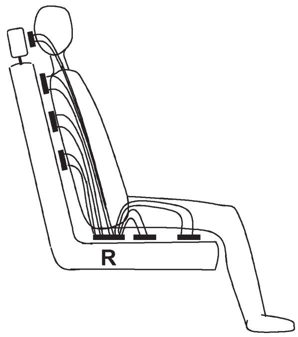

Fig. 5. Pictorial representation of electric field pattern of the proposed method during AO. An adult occupant, when normally seated, makes good capacitive coupling with R and all transmitters.

the transmitter to the receiver electrode increases in comparison with its value during the shielding mode. This is referred to as the coupling mode of operation, and it is shown using an equivalent circuit in Fig. 4.

When a person sits in a seat equipped with sensor electrodes, as shown in Fig. 1, any one of the aforementioned modes can occur depending on the occupant's position. If the occupant is far from the transmitter–receiver pair, the dominant mode of operation will be shielding and will change to coupling mode once the occupant comes very close to the sensor electrodes. As long as a person normally sits in the seat, the capacitance between the occupant's body and the receiver is stable, and the capacitance between the body and the transmitter gradually increases as the occupant gets closer to the transmitter. Thus, in this condition, the system is in the coupling mode of operation as far as the receiver and transmitting electrodes in the backrest area of the seat are concerned. When a passenger is about to occupy the seat, the electrodes in the sitting area of the seat will be in the shielding mode of operation but will change to coupling mode once the seat is occupied by the passenger. These are the properties exploited in the proposed method to sense human proximity in an automobile seat. A pictorial representation of the pattern of electric field lines between the transmitters and the receiver in the presence of an adult human body are shown in Fig. 5. A transmitter electrode is placed at the backrest head position. The receiver gets a signal from this electrode if the occupant sits normally as shown in Fig. 5. If the person sits in a forward bend (FB) position, the reception from the head position electrode as well as from the other electrodes in the top row of the backrest area will be reduced. Similarly, if the occupant turns left or right, then the corresponding capacitance values will be changed.

In the case of infant seat occupancy, the capacitive coupling with the backrest portion of the seat will be much lower than that for an adult occupancy (AO). Fig. 6 shows the electric field line pattern for such a case. The capacitances between the electrodes in the sitting area and receiver are important for sensing infant seat occupancy as they are in close proximity with the child compared to the electrodes in the backrest area of the seat. In the case of a rearward-facing child, due to the nonuniform volume distribution of the child body (the volume of the leg portions is lower than the volume of the head and shoulder portions), the capacitive coupling with the backrest

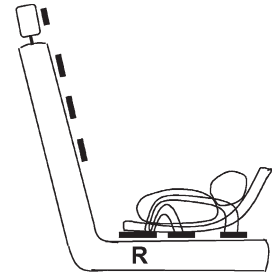

Fig. 6. Electric field line pattern of the sensor system in the presence of an infant in a rear-facing infant seat.

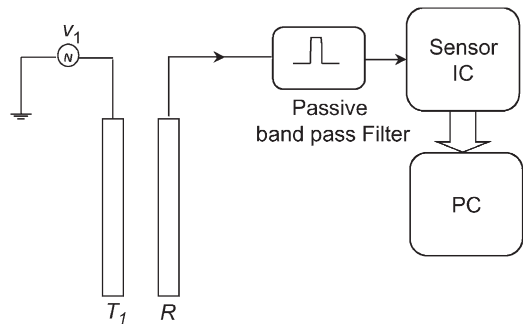

Fig. 7. Block diagram representation of the capacitance measurement system. The receiver signal is bandpass filtered and fed to the sensor IC. Output of the sensor IC is read and displayed by a PC. For brevity, only one transmitter–receiver pair is shown.

portion of the seat will be lower than that for a forward-facing child occupancy. Hence, for a rearward-facing child occupancy, the receiver gets lower signal levels from the transmitters placed in the backrest area of the seat compared to a forward-facing child occupancy. This information can be used as an indication for rearward-facing child occupancy. The conductance between the transmitter and receiver can also be measured along with capacitance. This will provide additional information that is useful to distinguish between the human body and other objects such as textbooks, a laptop, food, etc., that may be placed on the seat.

A. Principle of Capacitance Measurement

Fig. 7 shows a block diagram representation of the capacitance measurement system with a transmitter–receiver pair. A rectangular excitation is applied to the transmitter. A passive bandpass filter that follows the receiver attenuates unwanted out-of-band frequency components that may be present in the receiver signal [17]. A sensor integrated circuit (IC), based on a carrier-frequency measurement principle [13], [18], measures the capacitance between each transmitter and the common receiver. The capacitance values provided by the sensor IC are read, processed, and displayed in a personal computer (PC).

A functional block diagram of the capacitance measurement system based on the carrier-frequency principle is shown in Fig. 8. As explained in the previous section, the sensor consists of a set of transmitter electrodes and a common receiver electrode. Transmitter electrodes $T_1, T_2, \ldots, T_{11}$ are electrically connected to the buffer units $B_1, B_2, \ldots, B_{11}$ in order. When a measurement cycle is initiated, the control and logic unit (CLU)