TABLE I
RESULTS (NORMALIZED) OBTAINED WITH THE PROTOTYPE SYSTEM. CAPACITANCE VALUES BETWEEN EACH TRANSMITTER AND THE COMMON RECEIVER FOR ES, AO, FB, TR, TL, AND LU CONDITIONS WERE RECORDED. THE VALUE OF CAPACITANCE MEASURED BETWEEN T_4 AND R FOR THE CONDITION AO WAS 24.90 pF

Occupant status	Back rest area of seat						Sitting area of seat				Head
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
ES	0.132	0.106	0.106	0.125	0.126	0.136	0.145	0.144	0.144	0.157	0.036
AO	0.867	0.517	0.698	1.000	0.687	0.884	0.445	0.909	0.603	0.893	0.171
FB	*0.225*	0.842	0.875	*0.256*	0.996	1.125	0.658	1.564	1.042	1.363	*0.158*
TR	*0.362*	*1.482*	*1.262*	*0.237*	*0.245*	*0.389*	0.782	1.193	1.358	1.583	0.185
TL	*0.224*	*0.222*	*0.298*	*0.297*	*1.170*	*1.450*	0.675	1.645	1.235	1.601	0.173
LU	1.051	0.720	0.820	1.496	0.986	1.122	0.678	*0.115*	0.815	*0.124*	0.190

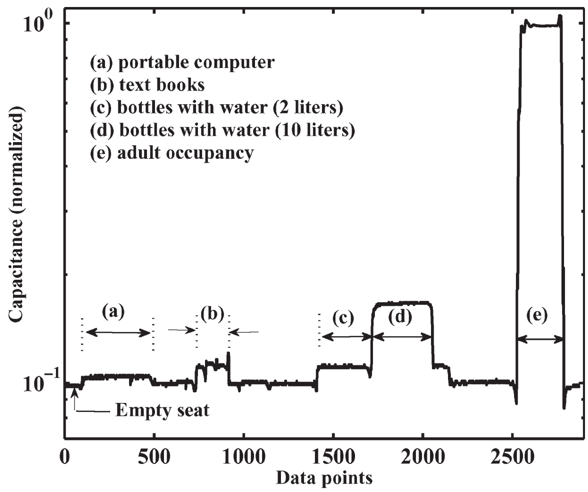

Fig. 11. Capacitance values measured between transmitter segment T_3 and receiver R for various scenarios. A capacitance measurement is also taken and shown for an AO. The results show that the change in capacitance for cases (a), (b), and (c) are very low in comparison with the change in capacitance observed for an AO. In case (d), 20 beer bottles each filled with 500 mL of water were placed in a basket, and the noticed change in capacitance was nearly 5.5 times lower than AO as the volume taken by the basket is a mix of water, glass, and air.

TABLE II
CAPACITANCE (NORMALIZED TO READING FOR AO) MEASURED BETWEEN TRANSMITTER T_3 AND RECEIVER R FROM THE PROTOTYPE FOR DIFFERENT CONDITIONS

Seat scenario	Capacitance
adult occupancy	1.00
adult on a wet blanket (2 mm thick)	1.07
adult with pull over (8 mm thick)	0.82
seat cover (10 mm thick)	0.04
infant seat (70 mm thick)	0.16
infant (10 kg) in an infant seat	0.27

commercially available baby seat with a thickness of 70 mm was placed on the seat. Then, a baby weighting 10 kg was allowed to sit on the baby seat, and an increase of 0.27 per unit was observed in the capacitance readings. These measurement results indicate promising occupancy detection capabilities of the developed sensing system.

Results obtained for different child seat conditions are presented in Table III. Capacitance values were recorded for Vacant Infant seat (VI), Forward-Facing baby (FF), Rearward-Facing baby (RF), Vacant Booster seat (VB), Booster seat with Baby (BB), booster Cushion with Baby (CB), and ten Beer bottles in a vacant booster cushion seat (BE) conditions. A baby-shaped dummy filled with water weighting 10 kg was used for the investigations. In Table III, $T_{(1,4)}$ indicates the average value $(T_1 + T_4)/2$ of the readings obtained from electrodes

TABLE III
CAPACITANCE VALUES OBSERVED FOR VI, FF, RF, VB, BB, CB, AND BE ARE PRESENTED

Test case	Back rest area			Sitting area	
	$T_{(1,4)}$	$T_{(2,5)}$	$T_{(3,6)}$	$T_{(7,9)}$	$T_{(8,10)}$
VI	0.118	0.104	0.123	0.175	0.136
FF	0.151	0.146	0.182	0.109	0.079
RF	0.139	0.131	0.164	0.073	0.094
VB	0.117	0.102	0.148	0.159	0.113
BB	0.162	0.148	0.260	0.101	0.080
CB	0.210	0.178	0.348	0.078	0.091
BE	0.153	0.144	0.158	0.124	0.108

T_1 and T_4. Similarly, $T_{(2,5)} = (T_2 + T_5)/2$, $T_{(3,6)} = (T_3 + T_6)/2$, $T_{(7,9)} = (T_7 + T_9)/2$ and $T_{(8,10)} = (T_8 + T_{10})/2$. As can be seen from Table III, for the conditions FF and RF, the capacitance values were increased for the electrodes from the backrest area as compared with the condition VI. This is because of the presence of the baby in the sensing volume and, hence, the increase in capacitive coupling between R and the transmitter electrodes in the backrest of the seat. During condition FF, the head and shoulder portions of the baby rest in between the receiver R and the transmitter electrodes in the backrest area. However, during condition RF, the same sensing volume will be occupied by the legs of the baby. Thus, during condition FF, higher capacitance values compared to those of condition RF were noticed for the electrodes in the backrest area. For conditions FF and RF, due to the shielding effect, the measured capacitance values for electrodes in the sitting area were lower than for condition VI. In the sitting area, the receiver and transmitter electrodes are in the same plane and, due to the presence of infant seats, there is more than 5 cm of vertical distance between the baby and the electrode plane. Thus, the child actually acts as a shield for the electrodes in the sitting area. Similarly, for conditions BB and CB, the electrodes in the sitting area are in shielding mode. Thus, for conditions BB and CB, the capacitance values observed for the transmitter electrodes in the sitting area were lower than the corresponding values obtained for condition VB. Also, for conditions BB and CB, due to the dominant coupling effect, the capacitance values read from electrodes in the backrest area were larger than the corresponding values obtained for condition VB. Readings obtained for ten filled beer bottles kept in the booster cushion seat are also given in Table III. As can be seen in Table III, the electrodes in the sitting area are in shielding mode, while those in the backrest area are in coupling mode. However, the shielding and coupling effects observed for this condition are significantly lower than those for conditions BB and CB, which permits one to distinguish between child occupancy and beer bottles placed in a booster seat or cushion.