SARTest Report 0113
June 2001

ON THE EFFECTIVENESS OF VARIOUS TYPES OF MOBILE PHONE RADIATION SHIELDS

MI Manning and M Densley

Report prepared by SARTest Ltd for the DTI

Indemnity

Sartest Limited makes no warranty, express or implied, with respect to the use of any information, method or process disclosed in this Report. Sartest Limited disclaims all liability for any loss, damage, injury or other consequence whatsoever arising from any use howsoever caused, including any resulting from error, omission or negligence in its application.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

With so many models of mobile phones available and so many types of shielding accessory products on the market, it is impractical to be exhaustive in accessory testing. In this report, we have surveyed the shield products available and classified them using four types: shielded case, earpiece pads and shields, antenna clips and caps, and absorbing buttons. Typical claims made for each category are summarised and certain misconceptions related to how they work are discussed.

Devices from each category have been subjected to comparative tests with and without the device in use to measure comparative SAR reduction figures. Many of the devices tested reduce SAR by reducing the radiated power output of the transmitting phone, and so results relating to the reduction in transmitted power have also been obtained. Measurements of the power received by the antenna of the test set controlling the phone are used to provide estimates of the link power reduction due to the devices. However since this measurement is only made at one location at fixed distance and direction from the phones being tested, the transmitted power comparisons are only indicative.

The results of SAR tests performed in this study show that many of the shield devices can reduce the maximum SAR from the handset by large amounts. Generally, however, this reduction is due to the device limiting the useful, radiated transmit power from the phone by a similar amount, which has the associated disadvantage of reducing the performance of the phone in weak signal areas or inside buildings.

Ideally, shield devices should reduce the SAR without impairing the antenna efficiency of the phone. So, the ratio of the SAR reduction to the transmitted signal reduction is a possible merit indicator for the accessories tested. In this Report, the results obtained for different categories of devices are mapped onto a graph of SAR reduction versus power reduction.

The test results show a wide variability in behaviour between devices. To help explain the variations, supporting investigative tests have been performed to aid with explanation of the test results. Investigations have included tests on different shapes of shield (screening) materials placed on the front of the phone. Reports of these tests show that the insertion of screening material between the phone and the head is only effective when the lateral dimensions of the screened area are comparable to the dimensions of the phone. Small shapes of the dimensions typically used for earpiece pads and shields have no significant effect in reducing SAR. Screens of similar dimensions to that of the phone do have significant effects, but it was found that the keypad has to be covered too.

For devices mounted on the front of the phone and for shielded cases, the device can increase the separation between the phone and the head. The magnitude of this effect has been investigated. Increasing the separation between the phone and the head also has a secondary benefit as the reduced absorption by the head increases the useful link power.

For devices affixed on the antenna of the phone or placed near the antenna, the efficiency of the antenna can be sharply reduced. Such antenna impairment is disadvantageous, because it makes the phone power-limited and reduces the radiated signal in all directions - not just in the direction of the head.

A combination of increased distance of the phone from the head and the application of large-dimension screening components between the head and the phone can limit SAR without causing similar reductions in the useful transmitted power from the phone. However, the overall bulk of the phone plus shield may be considerably increased.

Personal hands-free kits, which were tested in an earlier study for the DTI (Ref. 5), remain one of the best approaches for SAR reduction. By separating the antenna of the phone from the user's head, SAR is greatly reduced. To avoid exposure to other parts of the body, however, the phone should not be placed close to other parts of the body

Another option available for a user to reduce SAR levels is to select a phone with low SAR. A variability of SAR levels for GSM phones of a factor of 5 over a range of different models has been reported (Ref. 6). This means that a reduction of up to 80% could be achieved by swapping the model of your phone.

INTRODUCTION

Many countries have now defined limits on the maximum body dose from mobile phone handsets. These limits have been set by expert committees, which have examined the health issues. For the UK, a comprehensive review of the current state of understanding is presented in the Stewart Report (Ref 1).

Most mobile phone handsets in the UK are on GSM networks and are all expected to be operating within any of the applicable limits for Europe as well as being within the more stringent limits applied, for example, in the US.

Nevertheless, it is a user's choice whether to take a precautionary approach to limiting their own personal exposure to RF radiation and various approaches can be considered.

The DTI commissioned Sartest to review the devices on the market and test the effectiveness of representative products.

Misconceptions about how radiation emanates from mobile phones can lead to false expectations by users of the radiation reductions with some shield devices. Users also need to be made aware that shield devices may interfere with the normal operation of the phones causing reductions in call quality, area coverage and battery life.

SURVEY OF THE DEVICES ON THE MARKET

Following a survey of the devices on the market (as of November 2000), devices were grouped according to the following types:

- Shielded cases
- Earpiece pads and shields
- Antenna clips and caps
- Absorbing buttons
- Other

The survey was not exhaustive and the products available are changing rapidly. Certain products from each category were selected for testing as shown in Table 1.

CLASSIFICATION OF DEVICES BY TYPE AND SUMMARY OF CLAIMS MADE FOR EACH TYPE

Shielded cases

Some of these products claim high percentage reductions in SAR levels in the head based upon the blocking properties of metal screening layers. In some products, the screening fully encases the phones. In other designs, the shielding is mainly on the side facing the head.

Earpiece pads and shields

These products are often made from metallised mesh and typically take the form of small ovals placed over the earpiece. They often claim high percentage reductions for the material of which they are made, but the claims are based on results, which refer to tests made on signal transmission through big sheets of the material rather than the small fabricated shapes placed on the phones.

Antenna clips and caps

These either claim to be absorbing or deflective. Absorber-type devices contain amounts of material designed to absorb RF radiation. The deflective types have the objective of reducing the antenna radiation in the direction of the head and often take the form of a metal clip placed on the antenna, which covers the stub antenna on one side.

Absorbing Buttons

They are not usually specific about the basis of the claims.

Other

Various other styles of devices are marketed, but explanations of their effectiveness are often not based on technical principles.

PRODUCTS SELECTED FOR TESTING

Products were selected to be representative of the different categories of shield devices as listed above. There was no attempt to be comprehensive in the selection due to the large number of available products. Selected devices from each category were tested using the GSM phones listed in Table 1.

Table 1
GSM Phone models used for testing devices selected from each category

PRODUCT	CATEGORY	GSM PHONE USED FOR TESTING PHONE
SC-1	Shielded case	Nokia 3210, 5110, 7110
SC-2	Shielded case	Ericsson T10s
SC-3	Shielded case	Nokia 5110
SC-4	Shielded case	Ericsson T10s
ES-1	Earpiece shield	Nokia 3210, 7110 Ericsson A1018s, T10s
ES-2	Earpiece pad/shield	Nokia 3210, 7110 Ericsson A1018s, T10s
AC-1	Antenna clip	Nokia 5110, 7110 Ericsson T10s Trium MT140 Astra
AC-2	Antenna cap	Ericsson T10s
AB-1	Absorbing button	Nokia 3210 Ericsson A1018s
AB-2	Absorbing button	Nokia 3210 Ericsson A1018s, T10s
AB-3	Absorbing button	Nokia 3210, 5110, 7110 Ericsson A1018s, T10s

SELECTION OF A TEST METHODOLOGY

A great deal of study and consideration by international committees has gone into setting out the procedures, which should be used for testing the absorbed body dose (SAR) from mobile phone handsets. At present, these procedures do not offer additional guidance on how mobile phone accessories should be tested. However, for accessories, which attach to mobile phones, it is appropriate to follow accepted handset protocols as far as practicable.

The testing of an accessory is essentially a comparative evaluation - testing the effect with and without the device applied to a particular handset. As such, it should be possible to use relatively simple test equipment and still obtain useful comparative data. In fact, experience shows there are certain basic, minimum conditions for performing satisfactory comparative tests (Ref. 2). In the studies reported here, full scanning SAR tests have been used as the basis for the comparisons reported. It is also important to assess whether accessories impair the communications ability of the handset. Some information on this is afforded by the use of a special GSM test set to control the phones during the tests reported.

TEST METHOD EMPLOYED

The experimental arrangement used for SAR tests is shown below (Figure 1). The upright head-shell used is a specific shape produced by SARTest, which has the same shape and dimensions as the 'generic twin' phantom, which is usually used in the form of a horizontal bath. The upright version was produced from the published digital dataset of the phantom.

For this series of tests, the phantom was filled with 900 MHz simulated brain fluid. An E-field probe, calibrated in the simulant liquid by a thermal substitution method, is used to determine the SAR level in the liquid-filled head. The E-field probe is supported from a non-metallic robot arm for performing volume scans within the head shell. A plastic phone holder was used to position the phone against the phantom head.

The software first scans close to the wall of the phantom and subsequently scans a volume encompassing the region of maximum SAR. The maximum 1g and 10g SAR values are obtained by volume averaging the interpolated 3D scan measurements.

Further details of SARtest procedures can be found at the web site http://www.sartest.com .

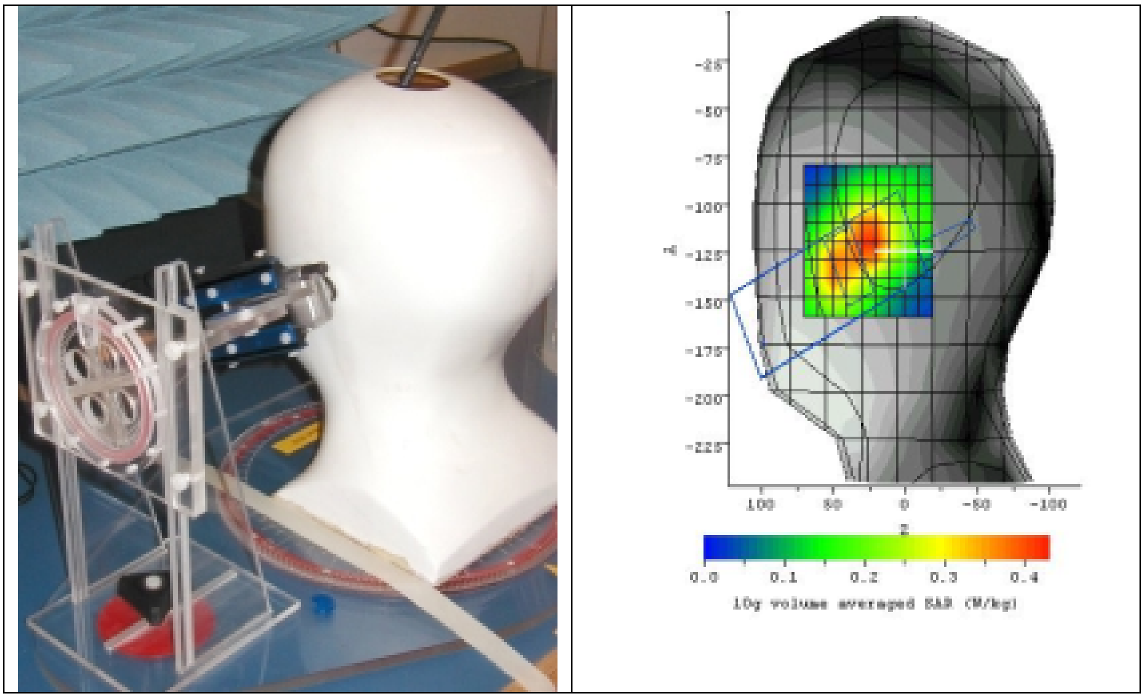

Figure 1. The experimental set-up used for the SAR testing.

The phones used in this study were controlled by a GSM test set (Wavetek 4107S). The test set was connected to a balanced dipole, which provided an air-link to the phones. For all tests a frequency of 902 MHz (channel 60) was used and the phones were set to maximum power (Control level 5). In addition to controlling the phone, the test set and dipole also measured the strength of the signal (in dB) emitted by the phone. This relative measure of phone signal strength was used as an indicator of phone performance. By using the dipole in a standard position, changes in phone performance with and without the device employed could be monitored.

For comparative purposes, each set of tests comprised SAR and relative link power measurements for the relevant phones with and without the shielding device being used. Thus the reduction (or otherwise) in SAR and relative link power caused by the device could be determined.

Unless otherwise specified, the phones were placed against the phantom head in the CENELEC 'touch' position (Ref. 3).

TEST RESULTS USING SELECTED PRODUCTS FROM EACH CATEGORY

Shielded Cases

Four shielded cases were tested in this study, these are referred to as**: SC-1, SC-2, SC-3**, and **SC-4**. The three **SC-1** cases tested were designed to fit Nokia 3210, 5110 and 7110 handsets. An Ericsson T10s phone was used to test the **SC-2** and **SC-4** cases, while the **SC-3** case was used on a Nokia 5110. The reduction in 1g SAR and the change in the relative link power between the phone and base station caused by each case is listed in Table 2.

Table 2:
Results of SAR tests on shielded cases

Phone	Device	Relative Link Power (dB)	Max E (V/m)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	Rel.Pwr Reduction(%)	1g SAR Reduction(%)
Nokia 3210	none	5.0	44.71	1.391	0.968		
	SC-1	-1.5	5.48	0.022	0.019	77.61	98.42
Nokia 5110	none	5.2	50.63	1.708	1.174		
	SC-1	-2.7	8.23	0.049	0.043	83.78	97.13
Nokia 7110	none	0.7	33.93	0.772	0.534		
	SC-1	-7.5	10.03	0.074	0.057	84.86	90.41
Ericsson T10s	none	2.4	28.45	0.552	0.448		
	SC-2	2.1	24.63	0.416	0.343	6.67	24.64
Nokia 5110	none	5.1	46.89	1.521	1.094		
	SC-3	6.1	42.27	1.245	0.892	-25.89	18.15
Ericsson T10s	none	2	23.5	0.528	0.345		
	SC-4	3.6	8.6	0.068	0.04	-44.54	87.12

It can be seen that the **SC-1** and **SC-4** cases were similarly effective in reducing SAR (Figure 2). The **SC-1** reduced SAR by between 90 and 98%, while the **SC-4** reduced SAR by 87%. The **SC-1**, however, also resulted in a significant reduction of relative link power (between 78 and 85%). On the other hand, the application of the **SC-4** actually resulted in the power of the signal transmitted by the phone increasing by 45%.

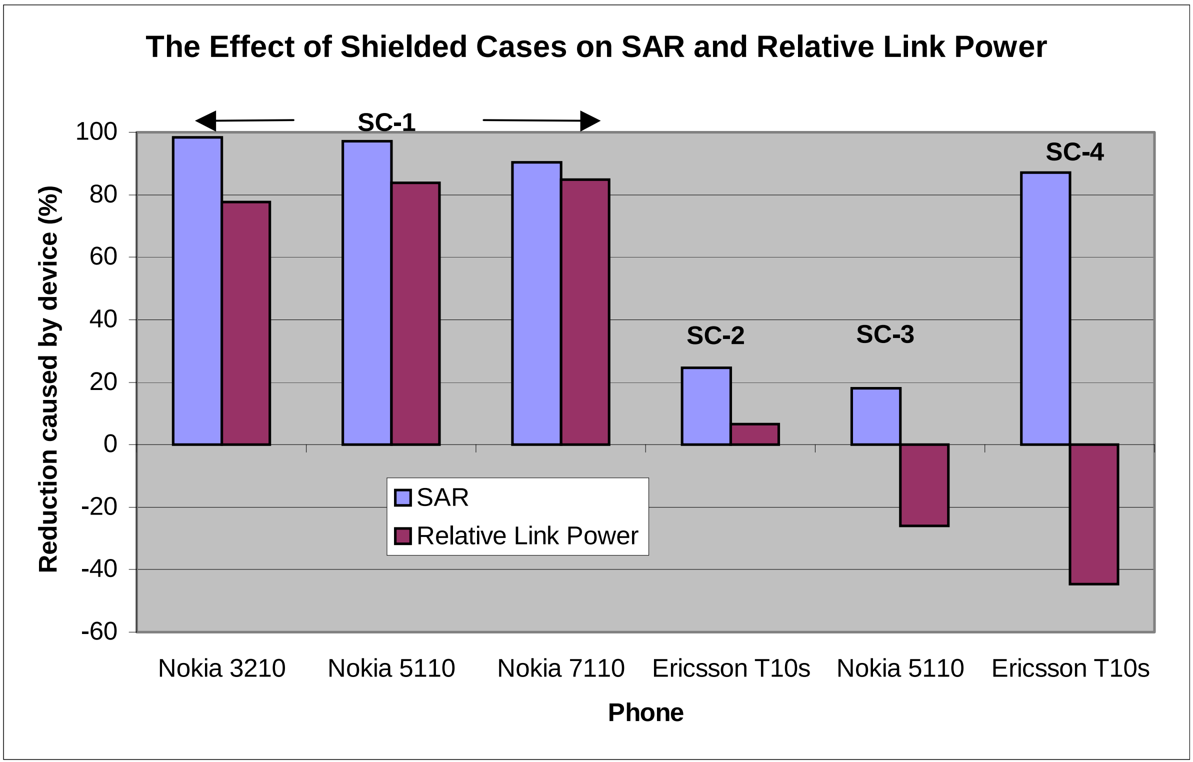

Figure 2. Percentage reductions of SAR and in the signal transmitted by the phone for the shielded cases tested.

The **SC-2** showed a moderate reduction in SAR (25%) when fitted to the Ericsson T10s, and a small reduction in power (7%). The **SC-3** case also resulted in a moderate percentage decrease in the 1g SAR (18%) but did increase the power of the signal transmitted by the Nokia 5110 by 26%.

Conclusion:

The **SC-1** and **SC-4** were the only cases tested that significantly reduced SAR. However, although **SC-1** reduces SAR, the reduction in link power is likely to impair phone reception and shorten phone battery life. A phone cased in the **SC-4**, however, should not suffer these adverse effects.

Earpiece Pads and Shields

The effect on SAR and link power of one earpiece shield, (**ES-1**) and one earpiece pad, (**ES-2**) was measured. The **ES-1** is an adhesive protective shield, designed to be attached to the earpiece of any mobile phone handset. The **ES-2** is a cushion that also sticks to the earpiece of any handset. Both devices were tested on several phones.

For the SAR tests performed for this report the phones were generally placed against the phantom head in the CENELEC 'touch' position (Ref. 1). However, when phones are in this position, only a small part of the phone's earpiece is against the ear spacer of the phantom head. Thus, the full benefit of shields attached to the earpiece may not be seen. Therefore, for the testing of earpiece pads and shields, the various phones were also placed in the CENELEC '15 degree' position (Ref.1). This position allowed the shielding device to make better contact with the ear spacer of the phantom head, and thus be more likely to reduce SAR.

The results of testing the two devices are listed in Table 3.

Table 3:
Results of SAR tests on earpiece pads and shields

Phone	Device	Phone Position	Relative Link Power (dB)	Max E (V/m)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	Rel.Pwr Reduction(%)	1g SAR Reduction(%)
Nokia 3210	none	15 degree	5.6	29.35	0.581	0.445		
	ES-1		5.6	29.13	0.586	0.438	0.00	-0.86
Ericsson A1018s	none	15 degree	6.2	26.19	0.442	0.335		
	ES-1		6	23.66	0.394	0.317	4.50	10.86
Ericsson T10s	none	cheek	-0.1	30.69	0.654	0.5		
	ES-1		0.7	29.82	0.676	0.504	-20.23	-3.36
Nokia 7110	none	cheek	-6.5	21.41	0.299	0.216		
	ES-1		-7.2	20.98	0.304	0.225	14.89	-1.67
Nokia 3210	none	15 degree	5.6	29.35	0.581	0.445		
	ES-2		6.3	28.56	0.563	0.442	-17.49	3.10
Nokia 3210	none	cheek	2.4	45.74	1.366	0.967		
	ES-2		2.3	46.13	1.354	0.948	2.28	0.88
Ericsson A1018s	none	cheek	5.7	44.53	1.352	0.952		
	ES-2		5.7	47.91	1.616	1.124	0.00	-19.53
Ericsson A1018s	none	15 degree	6.2	26.19	0.442	0.335		
	ES-2		7.1	26.02	0.482	0.361	-23.03	-9.05
Ericsson T10s	none	cheek	-0.1	30.69	0.654	0.5		
	ES-2		1.4	32.92	0.703	0.527	-41.25	-7.49
Nokia 7110	none	cheek	-6.5	21.41	0.299	0.216		
	ES-2		-7.7	21.66	0.323	0.235	24.14	-8.03

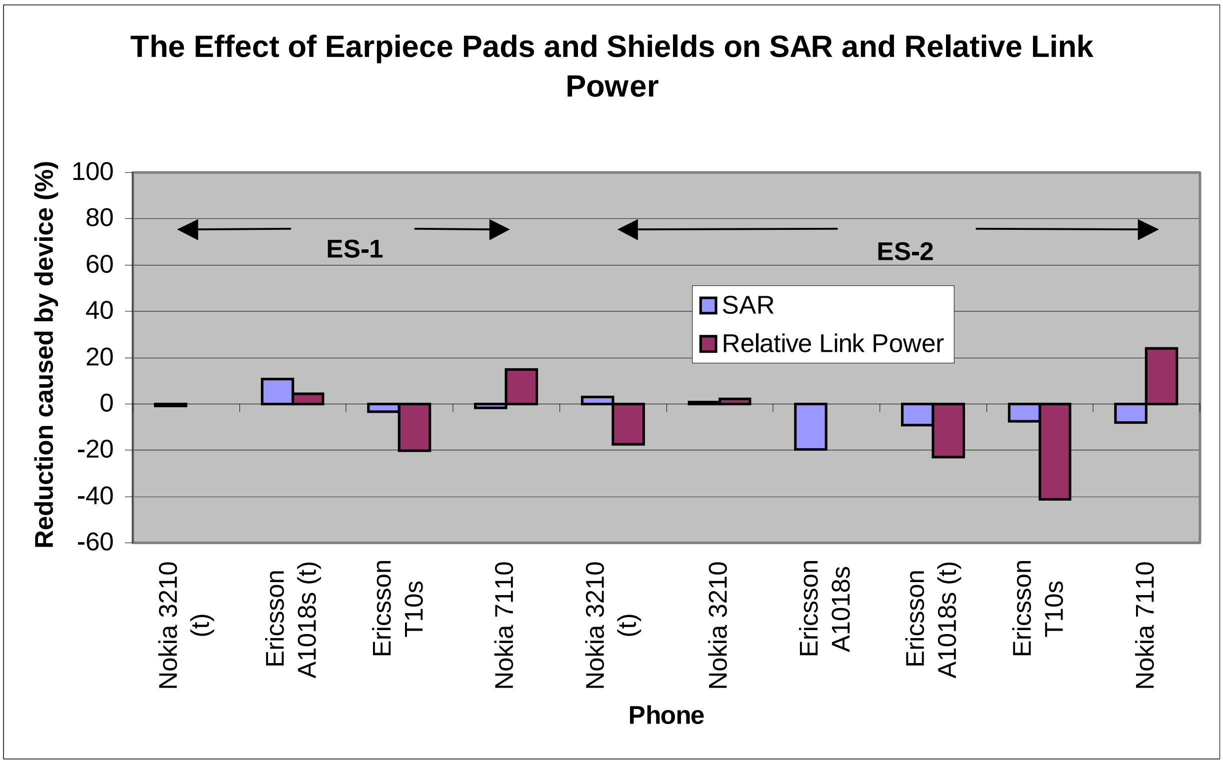

Figure 3. Percentage reductions of SAR and in the signal transmitted by the phone for the earpiece pads and shields tested. Note: (t) indicates that the phone was tested in the '15 degree' or 'tilt' position.

As illustrated in Figure 3, both **ES-1** and **ES-2** generally had little effect on SAR. The greatest SAR reduction caused by either device was 11% caused by **ES-1** when used on the Ericsson A1018s. Generally, the change in relative link power was within the uncertainty level for the measurement. However, an increase in link power of 41% was observed when **ES-2** was used on the Ericsson T10s, when tested in the 'cheek' position.

Conclusion:

Overall, it was found that earpiece pads and shields are ineffective in reducing SAR levels.

Antenna Clips and Caps

One antenna clip was tested (**AC-1)** and an antenna cap was also tested (**AC-2)**. **AC-1** is a device that clips onto the antenna of a phone while **AC-2** fits over the antenna. Both were found to be very effective in reducing SAR, but also resulted in significant reduction of phone link power. The exception to this was the **AC-1** when used on the Ericsson T10s, which resulted in more moderate reduction (Table 4 and Figure 4).

Table 4:
Results of SAR tests on antenna clips and caps

Phone	Device	Phone Position	Relative Link Power (dB)	Max E (V/m)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	Rel.Pwr Red(%)	1g SAR Red(%)
Ericsson T10s	none	cheek	2.5	29	0.605	0.488		
	AC-1		0.5	22.12	0.348	0.276	36.90	42.48
Nokia 7110	none	cheek	1.4	33.3	0.761	0.544		
	AC-1		-21	3.06	0.007	0.006	99.42	99.08
Nokia 5110	none	cheek	5.2	48.48	1.53	1.07		
	AC-1		-2.1	16.82	0.195	0.15	80.05	87.25
Trium MT140 Astra	none	cheek	4.0	47.58	1.571	1.124		
	AC-1		-6.1	9.23	0.059	0.051	90.23	96.24
Ericsson T10s	none	cheek	-1.5	24.4	0.569	0.369		
	AC-2		-11	7.3	0.051	0.034	88.78	91.04
Ericsson T10s	none	15 degree	-2.8	24.2	0.558	0.364		
	AC-2		-12.5	6.3	0.038	0.025	89.28	93.19

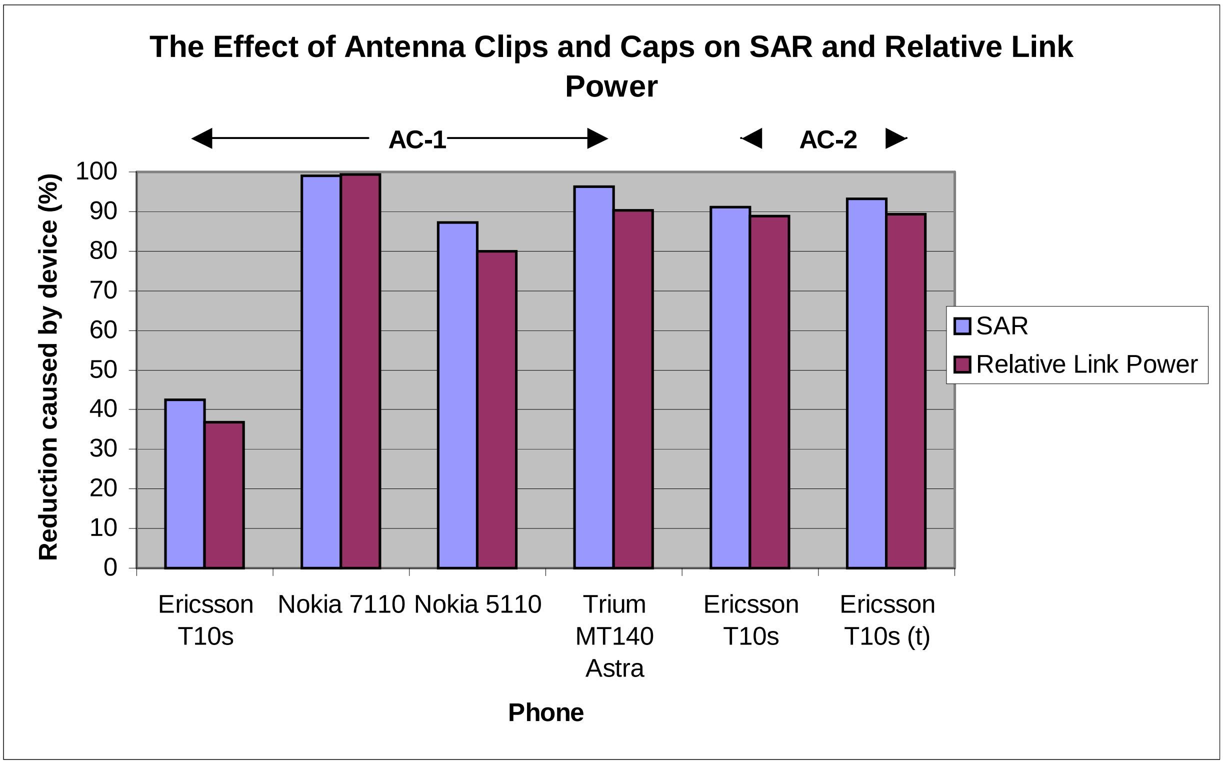

Figure 4. Percentage reductions of SAR and in the signal transmitted by the phone for the antenna clips and caps tested. Note: (t) indicates that the phone was tested in the '15 degree' or 'tilt' position.

Conclusion:

Although SAR was reduced significantly (often over 90%) when an antenna clip and cap were tested, the similarly great reduction in relative link power is likely to result in poor phone reception and reduced phone battery life.

Absorbing Buttons

There are a number of different absorbing buttons on the market that the suppliers claim to reduce SAR. Three such products tested are referred to as **AB-1**, **AB-2** and **AB-3**. These devices may be attached to any part of a handset and so a large number of tests were performed with the devices in different positions.

The **AB-1** was placed on the back of the Nokia 3210 and the Ericsson A1018s. The position of the device was aligned with the 'Nokia' label on the back of the 3210 and the 'Ericsson' label on the back of the A1018s.

The **AB-2** and **AB-3** buttons are small enough that they may be placed on virtually any part of the handset, including the antenna. For these tests, they were placed on the back of the handset, on the top face of the handset (near the base of the antenna) or on the antenna itself.

A full list of results for the three absorbing buttons is shown in Table 5. Figure 5 shows a graph of the results for each device in its most effective position (in terms of SAR reduction) for a selection of phones. It can be seen that none of the devices are very effective in reducing SAR. They also have little effect on the link power of the phones.

Table 5:
Results of SAR tests on absorbing buttons

Phone	Device	Position	Relative Link Power (dB)	Max E (V/m)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	Rel.Pwr Red(%)	1g SAR Red(%)
Nokia 3210	none		4.4	39.85	1.086	0.755		
	AB-1	below label	4.8	39.02	1.051	0.761	-9.65	3.22
	AB-1	above label	4.8	42.43	1.199	0.833	-9.65	-10.41
	AB-1	above left of label	3.7	34.82	0.847	0.620	14.89	22.01
	none		4.8	39.57	1.099	0.778		
	AB-1	above left of label	4.5	39.32	1.029	0.736	6.67	6.37
Ericsson A1018s	none		4.9	39.83	1.083	0.763		
	AB-1	on label	4.8	39.12	1.041	0.750	2.28	3.88
Nokia 3210	none		4.4	39.85	1.086	0.755		
	AB-2	back	4.2	38.41	1.035	0.718	4.50	4.70
	AB-2	back	4.2	38.02	1.013	0.704	4.50	6.72
	none		4.8	39.57	1.099	0.778		
	AB-2	top	4.9	38.72	1.091	0.764	-2.33	0.73
Ericsson A1018s	none		4.9	39.83	1.083	0.763		
	AB-2	antenna	4.7	36.76	0.902	0.673	4.50	16.71
	AB-2	top	5.0	37.71	1.005	0.713	-2.33	7.20
Ericsson T10s	none		2.5	28.11	0.540	0.440		
	AB-2	antenna	2.5	27.35	0.507	0.415	0.00	6.11
	AB-2	top	2.3	25.57	0.455	0.361	4.50	15.74
Nokia 3210	none		4.6	41.09	1.151	0.797		
	AB-3	top	4.6	43.94	1.167	0.834	0.00	-1.39
	AB-3	back	4.6	40.86	1.151	0.805	0.00	0.00
Ericsson A1018s	none		5.1	42.04	1.113	0.806		
	AB-3	back	4.7	38.8	1.017	0.869	4.50	8.63
Ericsson T10s	none		2.1	28.01	0.550	0.420		
	AB-3	back	2.1	26.9	0.524	0.404	0.00	4.73
	AB-3	antenna	2.1	27.69	0.548	0.418	0.00	0.36
	AB-3	top	2.2	27.67	0.528	0.421	-2.33	4.00

Nokia 5110	none		5.1	51.19	1.720	1.209		
	AB-3	back	5.1	51.46	1.802	1.190	0.00	-4.77
Nokia 7110	none		1.6	32.43	0.699	0.500		
	AB-3	back	1.6	31.09	0.671	0.488	0.00	4.01

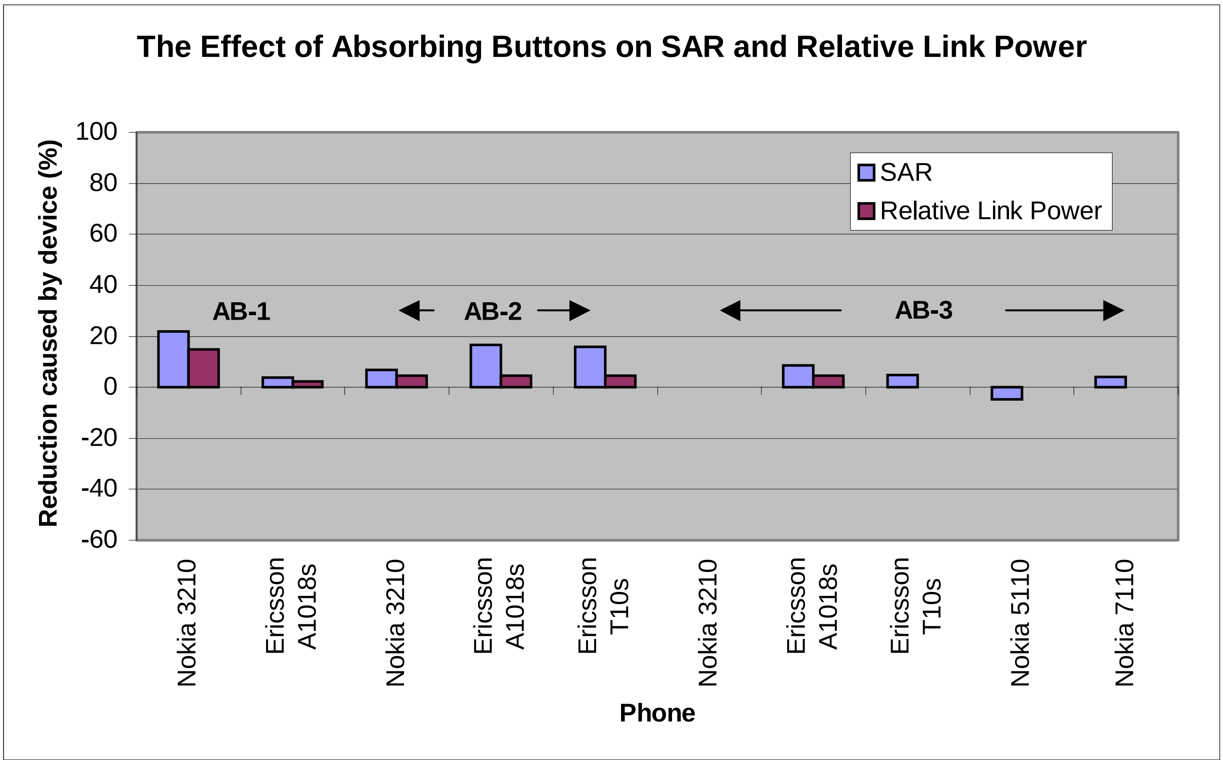

Figure 5. Percentage reductions of SAR and in the signal transmitted by the phone for the absorbing buttons tested. The graph only includes results for each device in its most effective position

Conclusion:

Absorbing buttons were found to reduce SAR by up to 20% dependent upon where they were placed on the phones. There was little impairment of link power.

INVESTIGATIVE TESTS OF THE EFFECTS OF DIFFERENT SHAPED SHIELDING LAYERS

To investigate the factors that contribute to the effectiveness of phone shields, eight separate shapes of aluminium foil were prepared and applied to a GSM phone. Tests were performed with a GSM phone operated at constant power on the 900MHz GSM band.

A Maxon 3204 GSM phone controlled to constant full-power output on the GSM 900MHz band was used to test the SAR reductions obtained with the differently-shaped aluminium foil. Tests were made using a GSM test set from Rohde and Schwarz (CTS50/55). With the test set, calls were established using maximum mobile transmit power on Channel 60.

The test shapes employed for testing are shown in Figure 6. Shapes were prepared from 20 micron aluminium foil.
The dimensions of the test pieces are listed in Table 6. The Maxon 3204 phone used has a maximum width of 50mm and a case length of 130mm. The stub antenna extends a further 20mm above the top of the phone.

The phone was mounted in a positioner (see Fig. 1) and held against the LH ear of the phone in the FCC normal use position. The charger lead to the phone was left connected for the whole duration of the tests so that constant power was assured and to avoid disturbing the phone. The phone was set a small distance away from the 20mm diameter ear spacer so that the test pieces could be inserted and removed with no alteration of the phone positioning.

The test sequence was as follows. With a call established using the test set, the phone was switched to constant full power. Using the scanning system, a SAR scan was performed to find the maximum 1g SAR value. The test pieces were then inserted one after the other between the phone and the phantom and the SAR measurements were repeated. At the end of the tests, another scan was performed with no test piece in place to check that conditions had not changed during the test.

Test pieces coded A and B were centred over the speaker aperture of the phone with the long side across the width of the phone. Piece C was placed at the top of the phone so that the tab covered the antenna region. Piece D was similarly placed but extended down over the whole phone. Piece E covered just the body of the front of the phone. Piece F was placed as with piece D. Piece G was centred over the top half of the phone and piece H covered the full length of the phone and was folded back to partially cover the sides as well.

The results obtained are listed in Table 7.

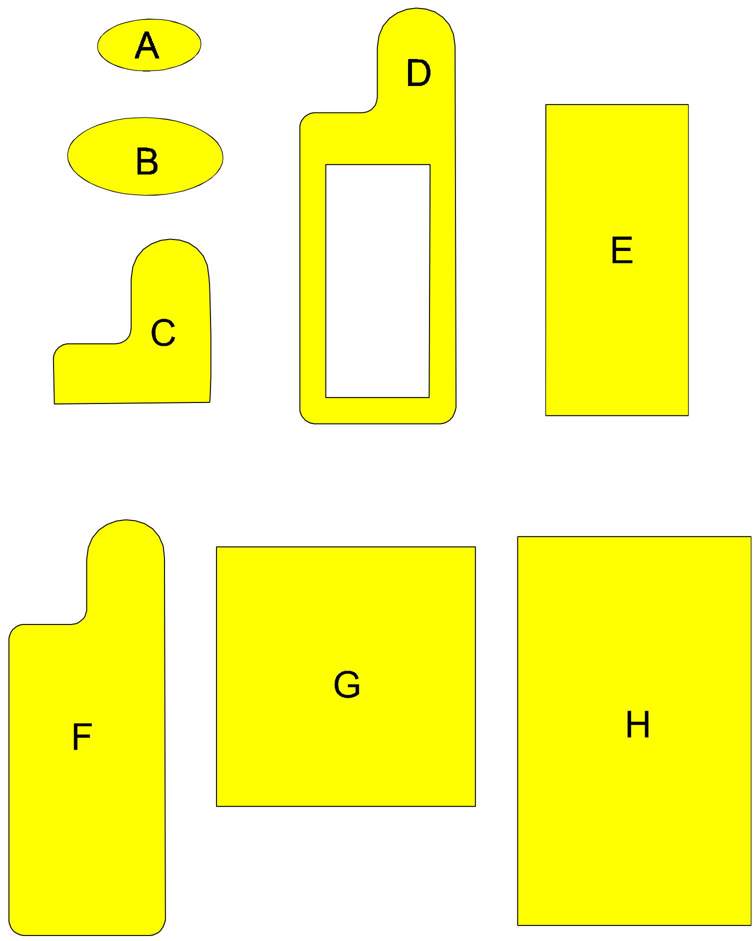

Figure 6 . The shapes prepared from aluminium foil. Test results are referenced to the letter code shown above. The dimensions are given in Table 6.

Table 6
Major dimensions of test pieces employed

Code identifier	Dimensions
A	Ellipse 40mm x 20mm
B	Ellipse 60mm x 30mm
C	Width 60mm; height 64mm
D	Width 60mm; height 180mm with keypad cut-out width 40mm; height 90mm
E	Width 55mm; height 120mm
F	As shape D but without cut-out
G	Width 100mm; height 100mm
H	Width 90mm; height 150mm

Table 7
SAR results obtained using a Maxon 3204 phone at the LH ear of the phantom operating at full power on the 900 MHz GSM band. SAR reductions obtained with each test piece are included.

Configuration	Al foil test shape Max. 1g SAR values (W/kg)	Reduction using Al foil (%)
Control at start of tests	0.53 (no test piece used)	
A	0.53	0
B	.50	6
C	.47	11
D	.77	-45 (worsening of SAR)
E	.12	77
F	.09	83
G	.11	79
H	.11	79
Control at end of tests	0.52 (no test piece used)	

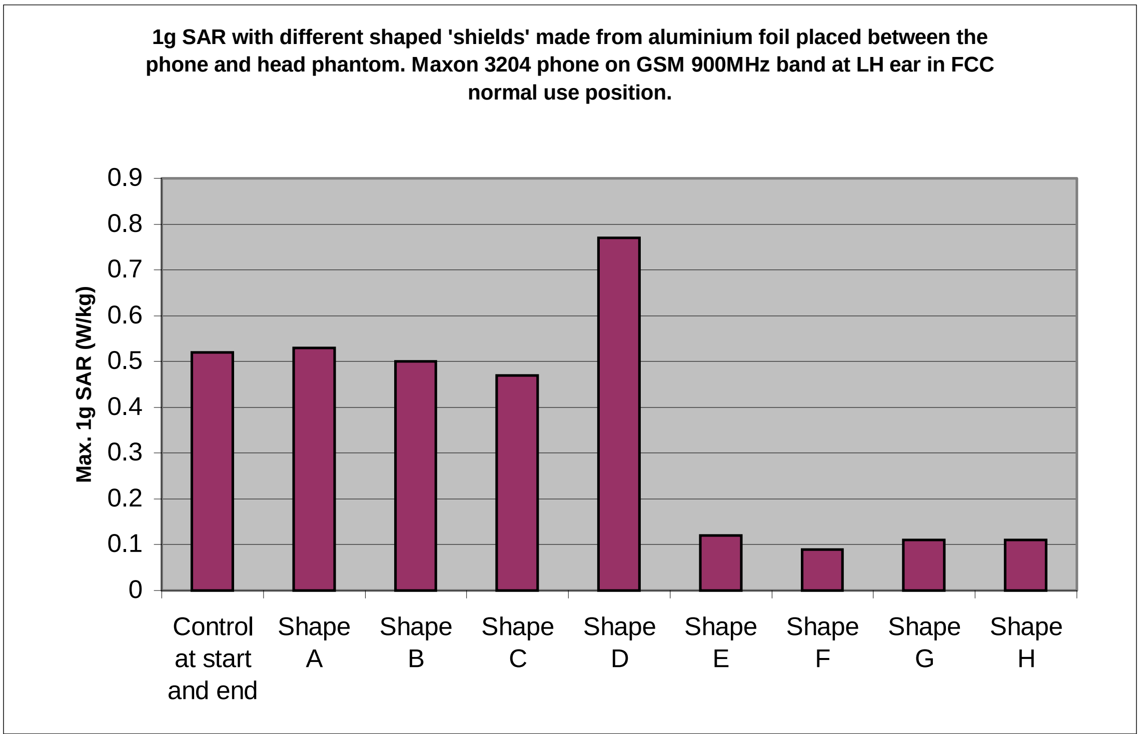

Figure 7. Results of Table 7 shown graphically. Note that shape D, which has the keyboard cut-out, causes an increase in SAR compared to the control.

When a large sheet of metal foil is held between a phone and the user's head, SAR can be reduced almost completely. However, such a sheet is impractically large for use in a shielding design and so tests were conducted on smaller pieces of aluminium foil shaped as in Figure 6. The shapes used are intended to represent those, which might be relevant for designing a shield device and range from small ovals up to larger sheets that fully cover the front of the phone.

Care was taken to ensure constant transmission conditions from the phone over the full test duration of the tests. The test pieces could be inserted and removed without disturbing the phone positioning.

The test results show that foil shapes can make significant reductions to the SAR levels in the phantom head provided that the dimensions of the shape are large enough. The smaller oval shape (shape A), when placed over the earpiece region, caused no measurable reduction and the larger oval shape (B) lead to a measured reduction in the maximum 1g SAR of 8%.

Shape F, which covered the whole of the face of the phone showed a SAR reduction of 83% but such a component has to be designed carefully. Tests with a similarly shaped piece with an added cut-out for the keypad (shape D) actually caused a significant increase in the SAR level in the phantom head.

Comparison of the results obtained with shape D and shape F suggest that the keypad region of the phone also needs to be screened. Some phone shield cases on the market do employ a fine metallic mesh over the keypad and manage to ensure that the keypad mesh is still transparent.

INVESTIGATIVE TEST OF DEVICE EFFECTS ON ANTENNAS

To help explain how effects arise when shield devices are clipped round or over handset antennas, the effects of placing short lengths of copper wire wrapped round a typical stub antenna were measured. It was found that the large reductions in SAR and the link performance of the antenna found with proprietary shield devices can also be reproduced with such an arrangement.

Placing the copper wire round the antenna reduced the measured SAR by 80% and reduced the transmitted signal from the phone by 69%.

EFFECT OF DISTANCE FROM THE HEAD ON SAR AND SIGNAL STRENGTH

A practical way to reduce SAR from a handset is to move it further away from the head. Phone cases and devices that clip on the front of the phone tend to increase the distance of the phone from the phantom head used for testing and lead to measured SAR reductions. The results shown in Figure 8 illustrate this effect with an Ericsson T10s phone. In addition to the direct reduction in SAR as the distance is increased, the power received by the test set is increased due to the reduced absorption in the head. In a network, where the power of the phone is dynamically controlled, this might enable a power reduction, which would reduce SAR further. In Figure 8, the measured reduction of SAR with distance has been adjusted to allow for this effect. The overall effect is for SAR reductions of a factor of approximately 4 times as the phone is removed 20mm from the ear of the phantom.

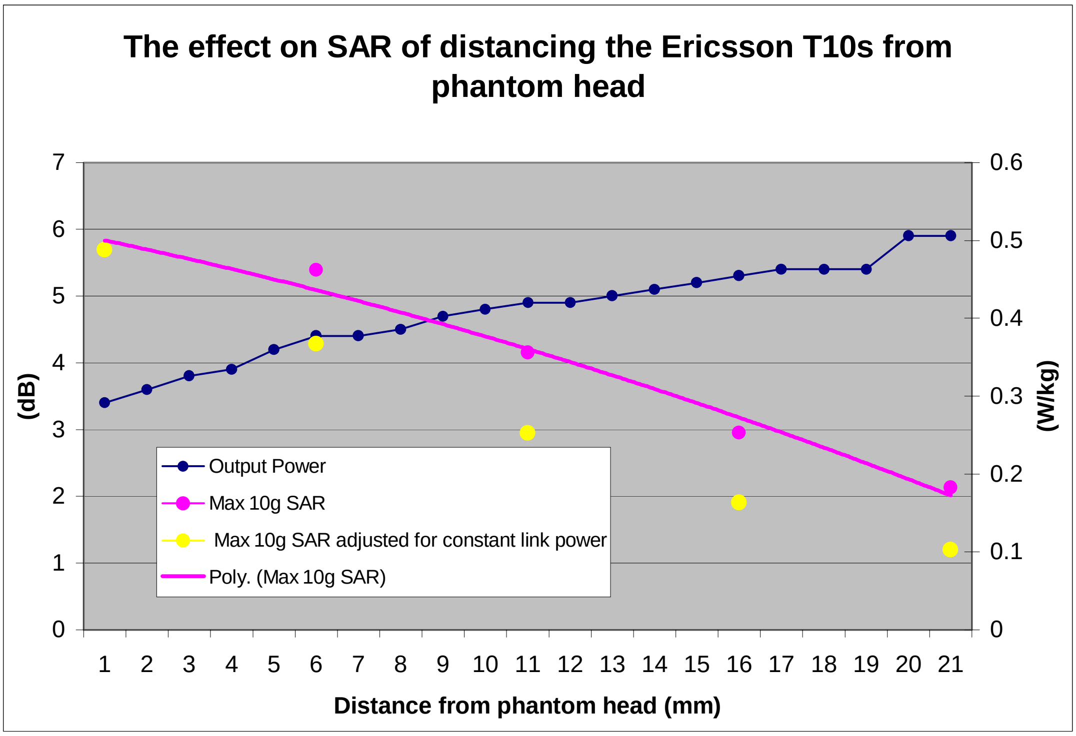

Figure 8. Reductions in 10g SAR with increased spacing between a phone and the phantom ear. (see text for explanation of the adjusted values).

POTENTIAL DISADVANTAGES OF SAR REDUCTION ACCESSORIES

There are certain potential disadvantages with the use of SAR reduction accessories that reduce the useful, radiated power from the phone. Because cellular networks control the power of the phone to maintain optimum link conditions, the network response to the fitting of a case will often be to raise the power demanded from the phone. This will mean that the battery is drained more quickly than otherwise when calls are being made. If the power, when raised, is still within the dynamic control range of the phone, in addition to the battery life reduction, the power (and hence SAR level) could be restored to the previous level negating the benefits of the shield devices.

When, however, the phone is driven at full power, no further power increases are possible and it is in this circumstance that shield devices lead to SAR reductions. However, if the useful radiated power is also reduced, the area of network coverage will be reduced. This effect has been analysed in a supporting study (Ref 4), which is described in the next section.

IMPLICATIONS FOR NETWORK OPERATION

To assess the reduced area coverage expected with the use of shield devices, which reduce the phone's transmitted power, a report was commissioned from MAC Consultants (Ref. 4).

In areas with a low user density, network operators seek to minimise the number of base stations, which are spaced as far apart as possible whilst still maintaining an acceptable level of coverage. The range of a base station is assessed using a 'link budget calculation', which takes into account all the various path losses in the system. The additional influence of a shield device can be considered to introduce additional losses in the system. Typical values for the attenuation due to shielded case has been shown in this study to vary between 0 and 20dB depending on the case design and phone used. Using the Hata/Okumura model, the effect of additional attenuation on the maximum communication distance was used to predict the area coverage reduction for a network designed for low user-density areas. Results for 900MHz and a 27m high base station are shown in Figure 9.

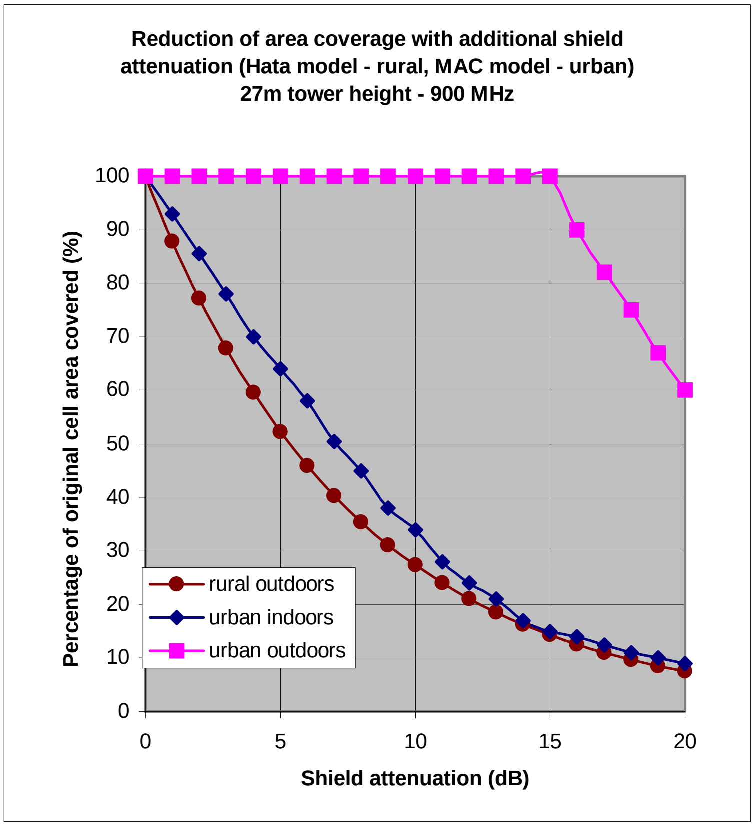

Figure 9. Reduction of area coverage due to phone shields predicted using two models. For the low user density network, a widely-used propagation model (Hata/Okumura) was used. The results for urban networks are average results obtained using the MAC model NP Workplace.

Multiple Access Communications Ltd (MAC) were also commissioned to advise on the more complex situation of the effect of shields on networks planned for high user density, urban areas. They used their radio planning tool, NP Workplace, to predict the coverage from various sites in two cities. They conclude that, since a 15dB allowance is commonly used in network planning to allow for the attenuation effects of buildings and network coverage is planned on this basis, no loss of coverage due to shield devices with less than 15dB attenuation would be expected in the urban outdoor environment. However, coverage in buildings would be reduced progressively with increased shield attenuation. In their study, 10 base stations in two cities were studies. Figure 9 includes the averaged results obtained from application of their planning model.

MISCONCEPTIONS ABOUT HOW SHIELDS WORK

There are some prevalent misconceptions about how shield might work. In Table 8, the perceptions arising from the marketing approaches used are compared with the findings of this study.

Table 8
The findings of this study compared with the perceptions encouraged by the marketing approaches used

Type of device	The perception	The findings
Shielded cases	Putting a phone in a screened case reduces the radiation to the head	It does, but it may also reduce the overall (useful) radiation from the phone. If the screening is too effective, the phone may not work as well.
Earpiece pads and shields	It is sometimes suggested that the skull blocks RF radiation but the ear canal lets it in. So, it seems a good idea to put a metal shield over the end of the ear canal.	In fact, the ear canal does not act in this way and the skull is not blocking the radiation elsewhere. Also, experimental tests described in this report show that the small metallic patches do not reduce SAR significantly.
Antenna clips and caps	The radiation that would have gone to your head is diverted somewhere else.	In fact, such devices impair the efficiency of some mobile phone antennas and result in power reductions in all directions. The implications of this are considered elsewhere in the Report. Users may have a mental image of RF radiation being emitted only from the antenna of a phone in the same way that light would be emitted from a bulb filament. This would explain why antenna shields seem a good idea. In fact, radiation is emitted from other parts of the phone and is not emanating from a point source.
Absorbing buttons	The buttons absorb radiation and stop it reaching the head	The reductions are unidirectional and the small amounts of absorbing material are not particularly effective. Without specific understanding of how phones work, it is possible that much is taken on trust without reliance on any sound physical basis for the benefits claimed.

PRACTICAL MECHANISMS FOR REDUCING SAR FROM PHONES

There are a limited number of physical mechanisms for lowering the body exposure from a particular phone. These include:

Increasing antenna separation from the body
Even small increases in the distance separating the phone's antenna from the head (or other part of the body) can lead to significant reductions in SAR. As an additional benefit, with less energy being absorbed by the body, other advantages occur as shown in this Report.

Impairing antenna efficiency
There are various ways in which the output power of the phone can be limited. However, GSM phones don't use more power than necessary in normal use and the power reductions have other detrimental effects.

Blocking radiation in the direction of the body
This is OK in principle, but phones aim to radiate power uniformly so that link power doesn't change as the user moves their head. Reducing the near-field radiation on the body-side is a desirable characteristic of a shield-design - but not often achieved. In the future, phone antennas may be designed with directional characteristics for SAR reduction.

Limiting phone maximum output power
GSM phones can adjust their output power by a factor of 100 times. The networks depend upon the higher power levels to ensure adequate call quality and network coverage inside buildings and in rural areas. So the designed maximum power of phones is an optimum power. If handsets had lower designed powers, there would be penalties such as, for example, a requirement for more base stations to pick up the weaker signals. Overall, this is not a simple option.

Using a hands-free kit
A hands-free kit greatly reduces the SAR in the head - but the phone should not be placed in contact with other parts of the body. A shielded case would be equally applicable for a phone clipped to a belt, for example, and could still be used with a hands-free kit, in which case, both head and body SAR would be reduced.

Selecting a low-SAR phone
Another option is to change your phone. Published lists already show that different phone models have widely differing maximum SAR levels. The benefit of this approach compared to a power-limiting shield is that the phone has the full power range and low maximum SAR. Power-limiting shields may give low maximum SAR, but they do this at the expense of limiting the level of the signal used to communicate with the base station.

DISCUSSION OF RESULTS AND RECOMMENDATIONS

With so many models of mobile phones available and so many types of shielding accessory products on the market, it is impractical to be exhaustive in accessory testing. In this report, we have surveyed the products available and classified them using four categories: shielded case, earpiece pads and shields, antenna clips and caps, and absorbing buttons. Typical claims made for each category have been summarised and certain misconceptions related to how they work have been examined.

Devices from each category have been subjected to comparative tests with and without the device in use to measure comparative SAR reduction figures. Many of the devices tested reduce SAR by reducing the radiated power output of the transmitting phone, and so results relating to the reduction in transmitted power have also been obtained. Measurements of the power received by the antenna of the test set are reported by the test set and these were used to provide estimates of the link power reduction due to the devices. However this measurement is only made at one location at fixed distance and direction from the phones being tested and the transmitted power comparisons are only indicative.

SAR test results performed in this study show that many of the shield devices can reduce the maximum SAR from the handset by large amounts. Generally, however, this reduction is due to the device limiting the radiated transmit power from the phone by a similar amount, which has the associated disadvantage of reducing the performance of the phone in weak signal areas or inside buildings.

Ideally, shield devices should be reduce the SAR without impairing the antenna efficiency of the phone and the ratio of the SAR reduction to the transmitted signal reduction is a merit indicator for the accessories tested. In Figure 10, the results obtained for different categories of devices are mapped onto a graph of SAR reduction versus power reduction.

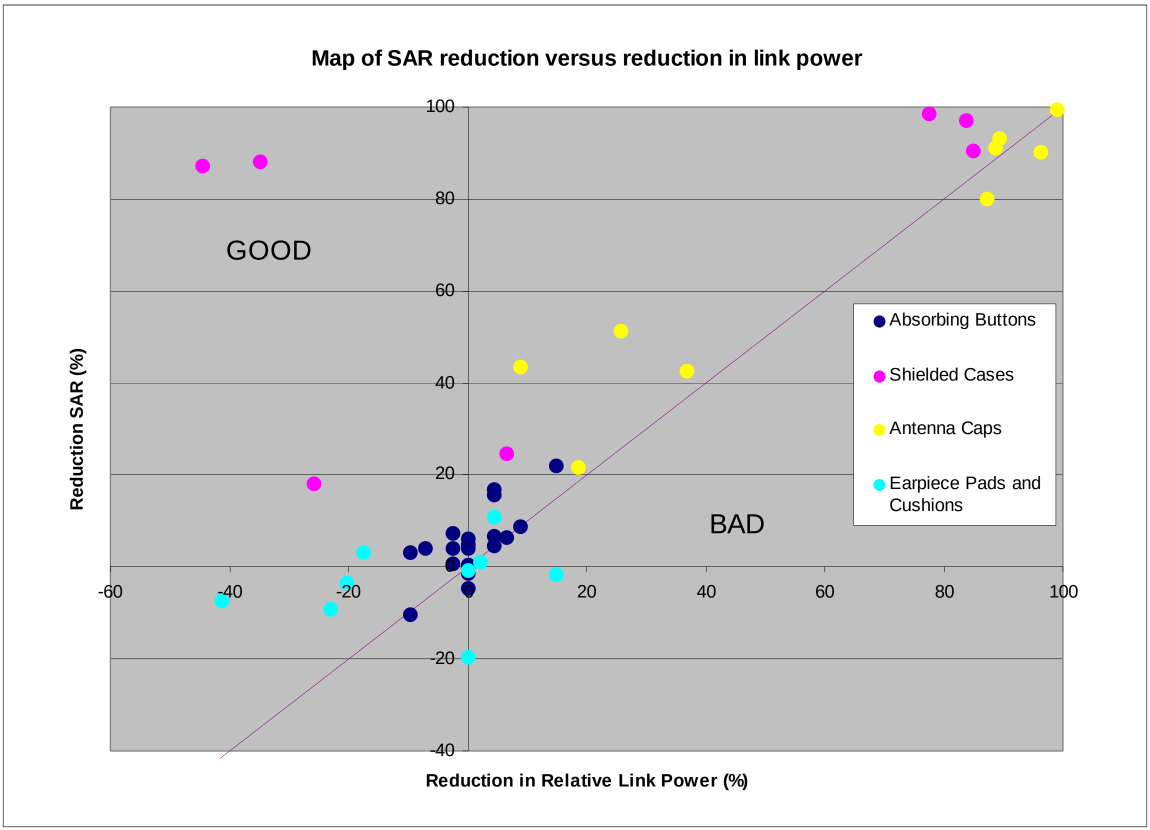

Figure 10. Summary of SAR reduction versus transmit power reduction for each category of devices

The test results show a wide variability in behaviour between devices. To help explain the variations, investigative tests have been performed on blocking shield materials.

These tests show that the insertion of screening material between the phone and the head is only effective when the lateral dimensions of the screened area are comparable to the dimensions of the phone. Small shapes of the dimensions typically used for earpiece pads and shields have no significant effect in reducing SAR. Screens of similar dimensions to that of the phone do have significant effects, but the keypad has to be covered too.

For devices mounted on the front of the phone and for shielded cases, the device can increase the separation between the phone and the head. The magnitude of this effect has been investigated.

Increasing the separation between the phone and the head has a secondary benefit. Since the power absorbed by the head is reduced, the useful link power is actually raised.

For devices that are affixed on the antenna of the phone or placed near the antenna, the efficiency of the antenna can be sharply reduced. This effect can easily be replicated by coiling a short length of wire around the antenna or, in fact, by placing a finger on the antenna.

It would seem that such antenna impairment is disadvantageous, because it makes the phone power-limited and reduces the radiated signal in all directions - not just in the direction of the head.

A combination of increased distance of the phone from the head and the application of large-dimension screening components between the head and the phone can limit SAR without causing similar reductions in the useful transmitted power from the phone. However, the overall bulk of the phone plus shield may be considerably increased.

Personal hands-free kits, which were tested in an earlier study for the DTI (Ref. 5), remain one of the best approaches for SAR reduction. By separating the antenna of the phone from the user's head, SAR is greatly reduced. To avoid exposure to other parts of the body, however, the phone should not be placed close to other parts of the body. In this situation, with the phone clipped to a belt or in a pocket, shielding material or additional spacing from the body could be beneficial for SAR reduction.

Another option available for a user to reduce SAR levels is to select a phone with low SAR. A variation of SAR levels for GSM phones of a factor of 5 over a range of different models has been reported (Ref. 6). This means that a reduction of up to 80% could be achieved by swapping the model of your phone.

REFERENCES

1) Report of the Independent Expert Group on Mobile Phones (Chairman Sir William Stewart), May 2000 (available at http://www.iegmp.org.uk).

2) Manning, MI. 'DTI sponsored measurements of SAR in mobile phone hands-free kits'.Proceedings of conference Approval 2000, Blenheim Palace, Oxford UK, 16th November 2000.

3) CENELEC European Specification ES59005 October 1998 - "Considerations for the evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30 MHz - 6 GHz."

4) 'A study into the effects of mobile radiation shields on the performance of cellular networks', Report by Multiple Access Communications Ltd, Report DTI0399/TDOC/99/001, March 1999.

5) Manning, MI and Gabriel, CHB, 'SAR tests on mobile phones used with and without personal hands-free kits', SARtest Report 0083, July 2000.

6) Article in Sunday Times Newspaper 3rd December 2000.