5 dB greater. (These results have been confirmed by tests in another multistorey building with metal partitioning.)

An antenna’s effective aperture is related to the inverse of the frequency squared and so at 1 m it would be expected that the path loss, which includes the antenna performance, would be 5.5 dB higher at 1700 MHz. This agrees well with the difference obtained here.

Discussion: The above results show that signal decay between adjacent floors, or through a substantial wall, will be 11 dB higher at 1700 MHz compared to 900 MHz. Obviously the more floors (wall) penetrated the greater the difference; increasing at 6 dB per floor. This means that for given system parameters and fourth-power decay rate, nearby operating ranges will be halved, with proportionally greater reduction further away. Any degradation in receiver sensitivity and transmitter performance at the higher frequency will naturally add to the reduced coverage.

In serving the needs of itinerant employees in a business complex, total building coverage will be a necessity. This could be achieved using a three-dimensional cellular-radio type layout of base stations with each cell’s range determined by the required quality of service. If, therefore, range is halved then eight times as many base stations will be required to serve a given volume. In some applications coverage across a single floor may dominate requirements, in which case four times as many base stations will be required at 1700 MHz compared with 900 MHz.

Table 1 POWER BUDGET

<table>
<thead>
<tr>
<th></th>
<th>900 MHz</th>
<th>1700 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mW</td>
<td>mW</td>
</tr>
<tr>
<td>Transmitter drive</td>
<td>25</td>
<td>333</td>
</tr>
<tr>
<td>Other circuitry</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Total</td>
<td>175</td>
<td>483</td>
</tr>
</tbody>
</table>

Alternatively, the transmitter power could be raised from 10 mW at 900 MHz to say 100 mW at 1700 MHz. If at 900 MHz the transmitter drive stage is 40% efficient and at 1700 MHz it reduces to 30% then the effect on the total power budget would be as shown in Table 1. Hence, at 1700 MHz 276% more battery power is needed, with a corresponding increase in battery volume to maintain the same time between charges. Serious cost implications result and it significantly raises the size and weight of the handset. For instance, if at 900 MHz the battery takes up 30% of the handset then the ratio of components, etc., to battery is 0.7:0.3. At 1700 MHz this becomes 0.7:0.8 and the overall size is 50% greater.

Conclusions: Radio coverage at 1700 MHz is significantly less than at 900 MHz. Operating ranges could easily be halved, resulting in a need for around four times as many base stations to cover an office building. Alternatively, transmitter powers could be raised to compensate for this, but this may then greatly increase the size of the personal terminal, or require more frequent recharging of batteries.

The move upwards in frequency will therefore impact system costs, unless technology can advance at a pace to offset the reduced range when such frequencies are commercially exploited for personal communications services.

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EASY PROGRAMMING FOR FAST COMPUTATION OF S-MATRIX SENSITIVITIES

Indexing terms: Microwave circuits and systems, Modelling, Matrix algebra, Circuit theory and design

An explicit formulation is presented for computing first- and second-order S-matrix sensitivities of microwave circuits. It can be very easily programmed in conjunction with a subnetwork growth approach to reduce CPU time and memory space requirements.

Introduction: The computation of S-matrix sensitivities is very important for microwave circuit analysis and optimisation. Some methods have been reported for evaluating first- and second-order sensitivities. As far as CPU time and memory space are concerned, the most interesting ones are those which are suitable for the subnetwork growth approach. However, the previous methods require many more connections than are required for circuit frequency response analysis only and are implicit for second-order sensitivity analysis, so that they bring about a considerable increase in program complexity. It is the purpose of this paper to show how one might overcome such difficulties by using the proposed formulation.

The minimum essentials relative to the subnetwork growth approach will be described first. Let E1, E2, …, Em be elements of a circuit and N1 = E1 be the first subnetwork. Then at an arbitrary connection step k (= 2, 3, …, m), subnetwork Nk−1, and element Ek being connected at cp, pairs of ports and having pck−1 and pck unconnected ports respectively, are characterised by

\[ b^r = S^a w \]

i.e.

\[ \begin{bmatrix} b_{pp}^r \\ b_{pc}^r \end{bmatrix} = \begin{bmatrix} S_{pp}^a & S_{pc}^a \\ S_{cp}^a & S_{cc}^a \end{bmatrix} \begin{bmatrix} a_{pp}^r \\ a_{pc}^r \end{bmatrix} \]

where a, b, and a, b, are the incident- and reflected-wave vectors relative to the connected and unconnected ports. The resulting network after the connection is characterised by

\[ b^r = S^a d^r \]

i.e.

\[ \begin{bmatrix} b_{pp}^r \\ b_{pc}^r \end{bmatrix} = \begin{bmatrix} S_{pp}^a & S_{pc}^a \\ S_{cp}^a & S_{cc}^a \end{bmatrix} \begin{bmatrix} a_{pp}^r \\ a_{pc}^r \end{bmatrix} \]

where the formulation of S^a can be found in Reference 7.

Let the resulting network be the updated subnetwork. We have

\[ S_{kk}^a = f^a S_{kk}^a \]

for k = 2, 3, …, m − 1

where f^a is a normal matrix of order (pk−1 + pk) and determined by

\[ a = f^a u^k \]

First-order sensitivity formulation: Let \( x \) be a generic variable. According to Tellegen’s theorem, one can obtain

\[ \frac{\partial S_{kk}^a}{\partial x} = \sum_{k=1}^{n} \frac{\partial S_{kk}^a}{\partial x_k} \frac{d_k}{d_x} \]

subject to \( \frac{\partial a^r}{\partial x} = 0 \) and \( b^r = S_{kk}^a a^r \), where \( p, q, c, d \) refer to an adjoint network.

Assuming all \( \partial S_{kk}^a/\partial x_k \) are known, we lay emphasis on deriving \( a^k \) and \( a^r \) in terms of \( a^r \) and \( 2^r \) respectively. Omitting the details, we have

\[ a^k = A^r a^r \quad \text{and} \quad a^r = S^a a^r \]

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Errata

In Table 1 sample a should read e and sample c should read a


On the ordinate of Fig. 2, $10^{-4}$ should instead read $10^{-2}$
A number of errors were inadvertently incorporated in the text during editing. The word 'increase' in the first line of the Introduction should read 'variation'; and the bottom three lines in both Tables should be replaced as follows:

Table 1:

| \Delta p, mbar/km | -213 < \Delta p < -198 | -198 < \Delta p < -64 |
| \Delta T, K/km  | -129 < \Delta T < 42  | -36 < \Delta T < 29  |
| \Delta e, mbar/km | -3 < \Delta e < 86  | -2 < \Delta e < 45  |

Table 2:

| \Delta p, mbar/km | -547 < \Delta p < -228 | -228 < \Delta p < -83  |
| \Delta T, K/km  | -33 < \Delta T < 66  | -66 < \Delta T < 37  |
| \Delta e, mbar/km | -132 < \Delta e < -12 | -114 < \Delta e < -18 |