shown in Fig. 1*b*. If the input to the analyser is a sequence $x(n)$, then the outputs at the terminals equal the DHTs of the N samples $x(n), x(n-1), \ldots, x(n-N+1)$.

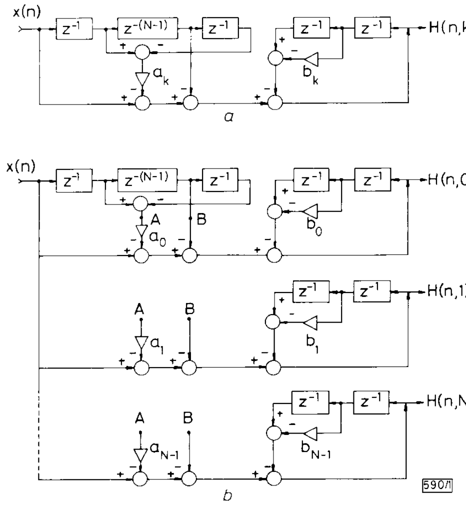

Fig. 1

a Architecture of recursive Hartley filter
b Real-time DHT analyser
$a_k = \text{cas}(-2\pi k/N)$, $b_k = 2\cos(2\pi k/N)$

Thus far, we have derived a recursive formula to calculate the running DHT. Another fact is shown that it is a good new approach to calculate the running DFT through the calculation of running DHT. Finally, based on this recursive formula we can derive a system function, the recursive Hartley filter (RHF), and by connecting N such systems in parallel, the real-time DHT analyser is constructed.

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PERSONAL COMMUNICATION RADIO COVERAGE IN BUILDINGS AT 900 MHz AND 1700 MHz

Indexing terms: Radiocommunication, Radiowave propagation, Digital communication systems, Mobile radio systems

Radio coverage in buildings is compared at 900 MHz and 1700 MHz, with the level of signal decay through floors identified. The reduction in range obtained at 1700 MHz leads to a consideration of the effect it has on system dimensioning, equipment size and costs.

Introduction: Considerable radio propagation data have been collected at 900 MHz for personal communication services, such as second-generation digital cordless telephones.[1,2] The imminent introduction of these products has heightened interest in the next evolutionary step towards the integration of cordless and cellular radio in a personal communicator, operating in the 1700 MHz band. However, it is important to consider the change in radio coverage which results from a move to higher frequencies and the effect this has on system dimensioning, transmitter power requirements, equipment size and costs.

To compare the coverage inside buildings at 1700 MHz with 900 MHz the following tests were performed in a modern multistorey office. The building was of standard steel frame construction with brick external walls and plasterboard internal partitions.

Measurements: A portable transmitter was moved around selected rooms throughout the building whilst a stationary receiver, located at the centre of the office block, monitored received signal levels. This receiver was attached to a dipole antenna and used a computer for processing, normalising and storage of the collected results. The portable transmitter could be operated at 900 MHz and 1700 MHz using appropriate quarter wavelength, with groundplane, antennas.

The results could be analysed using the conventional distance power law relationship as follows:

$$P = S + 10n \log_{10} d \qquad (1)$$

where P = path loss (dB), S = path loss at 1 m (dB), n = power law index, and d = distance between transmitter and receiver.

Hence, through fitting best straight lines to the collected data, the values of S and n can be obtained at both frequencies. However, it has been found that it is more appropriate to modify eqn. 1 as follows:

$$P' + kF = S + 10n \log_{10} d \qquad (2)$$

Here F represents the signal attenuation provided by each floor of the building and k the number of floors traversed, with P' the resulting path loss. If P' is now plotted against d then the spread in points about the resulting straight line fit is significantly reduced. In fact to ascertain the floor factor, F, the value is taken which produces the minimum mean square error in the data about the straight line.

Using the above approach the results shown in Fig. 1 were obtained at both frequencies. As can be seen the signal decay rates, n, are similar at both frequencies, but the floor factor is nearly 6 dB higher at 1700 MHz and the path loss at 1 m is

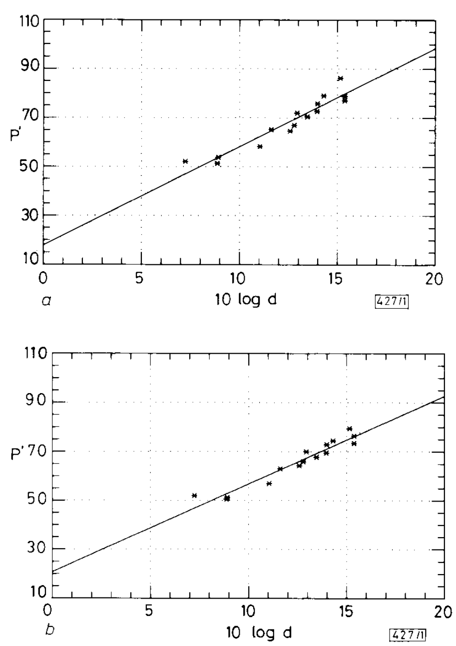

Fig. 1 *Radio coverage*

a 900 MHz, $F = 10$, $S = 16$, $n = 4$
b 1700 MHz, $F = 16$, $S = 21$, $n = 3{\cdot}5$

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[3] 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

	900 MHz	1700 MHz
	mW	mW
Transmitter drive	25	333
Other circuitry	150	150
Total	175	483

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.[1–6] As far as CPU time and memory space are concerned, the most interesting ones are those[1–3] which are suitable for the subnetwork growth approach.[7] 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 $E_1, E_2, \ldots, E_m$ be elements of a circuit and $N_1 = E_1$ be the first subnetwork. Then at an arbitrary connection step k ($= 2, 3, \ldots, m$), subnetwork N_{k-1} and element E_k, being connected at c_k pairs of ports and having p^n_{k-1} and p^e_k unconnected ports respectively, are characterised by

$$\boldsymbol{b}^w = \boldsymbol{S}^w \boldsymbol{a}^w$$

i.e.

$$\begin{vmatrix} \boldsymbol{b}^w_p \\ \boldsymbol{b}^w_c \end{vmatrix} = \begin{vmatrix} \boldsymbol{S}^w_{pp} & \boldsymbol{S}^w_{pc} \\ \boldsymbol{S}^w_{cp} & \boldsymbol{S}^w_{cc} \end{vmatrix} \begin{vmatrix} \boldsymbol{a}^w_p \\ \boldsymbol{a}^w_c \end{vmatrix} \qquad w = N_{k-1}, E_k \quad (1)$$

where $\boldsymbol{a}_c$, $\boldsymbol{b}_c$ and $\boldsymbol{a}_p$, $\boldsymbol{b}_p$ are the incident- and reflected-wave vectors relative to the connected and unconnected ports. The resulting network after the connection is characterised by

$$\boldsymbol{b}^k = \boldsymbol{S}^k \boldsymbol{a}^k$$

i.e.

$$\begin{vmatrix} \boldsymbol{b}^{N_{k-1}}_p \\ \boldsymbol{b}^{E_k}_p \end{vmatrix} = \boldsymbol{S}^k \begin{vmatrix} \boldsymbol{a}^{N_{k-1}}_p \\ \boldsymbol{a}^{E_k}_p \end{vmatrix} \quad (2)$$

where the formulation of $\boldsymbol{S}^k$ can be found in Reference 7.

Let the resulting network be the updated subnetwork. We have

$$\boldsymbol{S}^{N_k} = \tilde{\Gamma}^k \boldsymbol{S}^k \Gamma^k \qquad \text{for } k = 2, 3, \ldots, m-1 \quad (3)$$

where Γ^k is a normal matrix of order $(p^n_{k-1} + p^e_k)$ and determined by

$$\boldsymbol{a}^k = \Gamma^k \boldsymbol{a}^{N_k} \quad (4)$$

First-order sensitivity formulation: Let x be a generic variable. According to Tellegen's theorem,[5] one can obtain

$$\tilde{\alpha}^m \frac{\partial b^m}{\partial x} = \sum_{k=1}^{m} \tilde{\alpha}^{E_k} \frac{\partial S^{E_k}}{\partial x} a^{E_k} \quad (5)$$

subject to $\partial a^m/\partial x = 0$ and $\beta^{E_k} = \tilde{\boldsymbol{S}}^{E_k}/\alpha^{E_k}$, where β and α refer to an adjoint network.

Assuming all $\partial \boldsymbol{S}^{E_k}/\partial x$ are known, we lay emphasis on deriving $\boldsymbol{a}^{E_k}$ and $\tilde{\alpha}^{E_k}$ in terms of $\boldsymbol{a}^m$ and $\tilde{\alpha}^m$ respectively. Omitting the details, we have

$$\boldsymbol{a}^{E_k} = A^k a^m \qquad \text{and} \qquad \alpha^{E_k} = \mathscr{S}^k \alpha^m \quad (6)$$