CELLULAR RADIO

ETI's communications correspondent Keith Brindley casts an eye over cellular communications systems in the UK.

Whatever your point of view, modern electronic communications systems are pretty clever. How we use (or abuse) them is a different matter entirely. Personally, I can imagine little worse than the 'advantage' of a 'phone in my car. I have problems enough at home with the telephone ringing constantly, without having to suffer the same when I drive. Furthermore, I'm committed sufficiently as a serious motorist to feel the distractions of using a 'phone (or any means of telecommunications) in transit are dangerous and should not legally be allowed. Nevertheless, given the fact many people require telecommunications in order to do business, there is a need for a system such as cellular radio.

Mobile communications is not new. Mobile radio has been used by the military for nearly eighty years, and commercial organisations have been in operation providing systems to emergency services such as fire, police and ambulance for nearly as long. There are four other main types of mobile communications, which we should briefly consider before looking in depth at cellular radio itself.

Radiopaging. A call (generally digitally coded) is transmitted on a single frequency radio channel to a large number of receivers (sometimes nicknamed 'bleepers'). The call is headed by a receiver-specific code, triggering only one of the bleepers which correspondingly bleeps or otherwise indicates that a call has been received (Fig. 1). The call originator uses a normal telephone to dial the number dedicated to the receiver much as if the receiver is a telephone itself. However, the processing exchange routes the call to the receiver via a radio transmitter. In some sophisticated radiopaging systems a complete message is transmitted to the receiver and the user reads this on an LCD or similar display. Bleepers of more simple systems merely inform the user that a message is waiting. The user must then call a dedicated number via an ordinary telephone to receive the message.

Radiophone. Operating along the citizens' band lines, radiophones or 'walkie-talkies' as they are sometimes nicknamed are simple mobile receiver-transmitters, either hand-held or fixed in a car or base station. These use a single transmission frequency for both reception and transmission (Fig. 2). Use of a single frequency means only one user can transmit at a time, the other user in the communication link must wait until the first has finished before a reply can be made. This one-at-a-time operation is known as 'simplex' communication.

The bands of frequencies which the services use define the type of radiophone system. Citizens' band, for example, is so called because the service uses a band of frequencies which has been allocated for public citizens' use.

As a service, radiophone systems have significant drawbacks in addition to their simplex mode of operation. Users often have to queue, waiting for a free channel on which to transmit. This happens, particularly in urban areas where large numbers of users reside, or at busy times. Privacy is also impossible. Anyone with similar equipment can listen into a communication link.

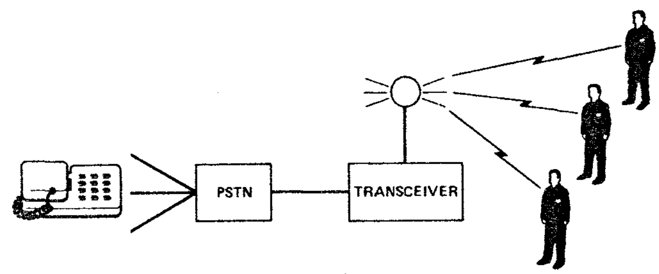


Fig. 1 Radiopaging.

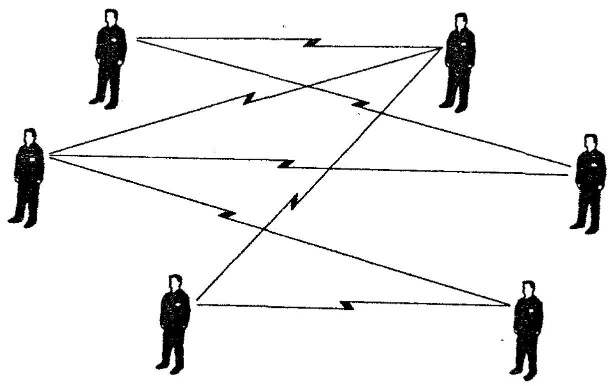


Fig. 2 Radiophone and CB radio.

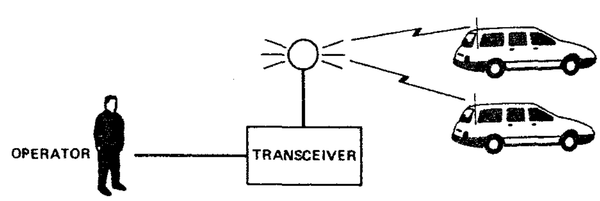


Fig. 3 Dispatch radio services.

Dispatch radio service. This is the sort of communications system used in taxis, ambulances, service vehicles and so on, in which a central or base station transmits and receives messages to and from mobile users (Fig. 3). The mobile users generally communicate only with the operator at the central station although some systems allow calls to be patched through from one mobile to another by the operator.

The disadvantages are fairly obvious. The number of mobile users on any one system is limited to the number of calls the operator can handle. Communication is simplex. Mobile users' transmitters can only be low powered so the distance over which the system

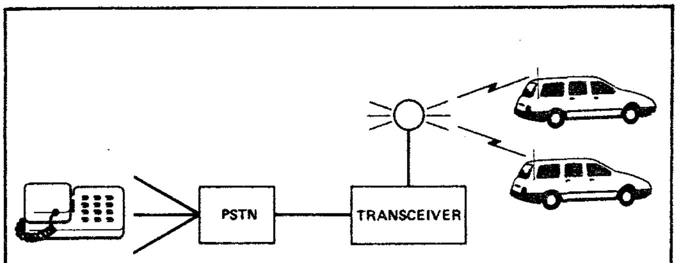


Fig. 4 Radio telephone services.

can be used is limited. Finally, with this service privacy is impossible.

Mobile telephone service. Commonly called radiotelephone services, the mobile telephone is linked over the air to the public switched telephone network (PSTN) so communication links with ordinary telephones can be set-up (Fig. 4). Communications are 'duplex', each user in the link able to talk at the same time.

This would seem the ideal mobile communications system. However, use of the available transmission frequency bands (HF and VHF) is not particularly economical and often a system may be busy, so long waits for a free channel can be expected.

A significant problem arises in the distance which a mobile user is from the central receiving station, and the consequent transmitter power. The further away the user is, the more powerful the transmitters must be. However, the more powerful the transmitters are the wider apart they must be to prevent interference with other transmitters of the same frequency or the fewer the available transmission frequencies. On the other hand, if low powered transmitters are used there is a good chance the mobile user will stray out of the transmission area during the call (the user *is* mobile, after all). Typically, quite powerful transmitters are used, with a limit to the number of channels available.

Privacy is also not possible in a standard system, although specialised systems can incorporate speech encryption — at a high cost.

One Better

It was the general poor quality of mobile communications and radio channel congestion which, in 1982, prompted the Government to allocate 30 MHz of radio frequency spectrum to a new mobile radio system, known as 'cellular' communciations. The system chosen was the 'Total access communications system' (TACS), a derivative of the already existing 'Advanced mobile phone service' (AMPS), developed by AT&T in the US.

Cellular communications systems are essentially an extension of existing mobile services. However, the use of computer controlled technology allows far greater economy of transmitting frequency bands and far greater efficiency. As far as the mobile user is concerned the receiving/transmitting apparatus is effectively an ordinary telephone, with all the usual telephone features (and more besides) and as easy to use.

Computer control of the switching apparatus means tremendous economy of the available frequency bands can be obtained. In turn, this means many more communication links can be made in the same number of frequency bands when compared with other mobile communications systems.

Finally, instead of a small number of relatively high powered HF or VHF transmitters being used to cover an area (as in radiotelephone systems), cellular communications systems use a very large number of low powered UHF transmitters. Again, it's computer control which allows this to work — calls can be automatically switched from one transmitter to the next as the mobile user moves between different transmitter reception areas.

We will look at each of these features of cellular communications in more depth.

Transmitter Power

Transmitter coverage in a mobile telephone service may be a circle with a radius of x km (Fig. 5). Outside this coverage zone is an interference zone, with a radius of about 5x km, in which the same radio frequencies used in the coverage zone cannot be used by another transmitter, otherwise interference of the two transmissions will probably occur. The same frequencies can be used outside the interference zone without interference occurring.

The key to the use of cellular communications is in the reduction in size of the coverage zones of the base stations (the receiver/transmitter) used. A smaller coverage zone means that fewer users will require the use of the base station. As a direct result of this, fewer channels are required to serve those fewer users.

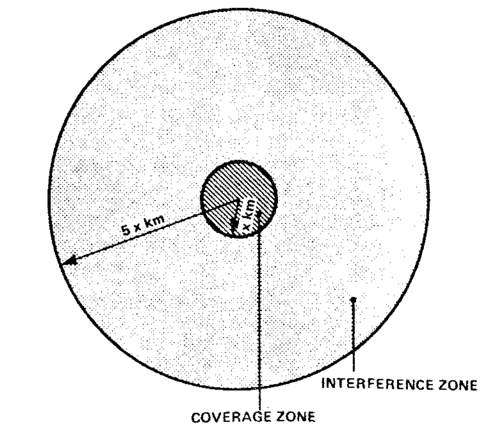


Fig. 5 Transmitter coverage.

In a cellular communications system the coverage areas are so small that they can be looked upon as 'cells' (hence the name) arranged in groups (known as 'clusters') over the land. Figure 6 shows seven-cell and 12-cell cluster arrangements. Others, such as four-cell and 21-cell arrangements, are also possible. Although each cell has a roughly circular coverage zone, they are usually thought of as hexagonal in shape and are much easier to draw because of this. Numbers within the cells merely indicate a particular frequency set of channels which transmitters in that cell use. Clusters are identical, in that correspondingly numbered cells in adjacent clusters use the same transmission frequencies.

The seven-cell cluster arrangement is ideal in terms of interference zones, as each base station is approximately five times the radius of its coverage zone away from the nearest base station with the same transmission frequency (measure it if you don't believe it!). So interference is unlikely. Any fewer cells in a cluster and corresponding base stations may be too close (and interference might occur). On the other hand, any more cells in a cluster mean that corresponding base stations would be further away than necessary and so transmission frequencies (and hence channels) are apparently being wasted.

However, the number of cells used in a cellular communications system depends on future requirements of the system, too. If more users than an existing arrangement can cope with wish to use the system, then two options are available.

Firstly, each cell can be split into seven smaller cells (ie, the cell itself becomes a cluster) so base station coverage zones become smaller and a greater number of users can be accommodated.

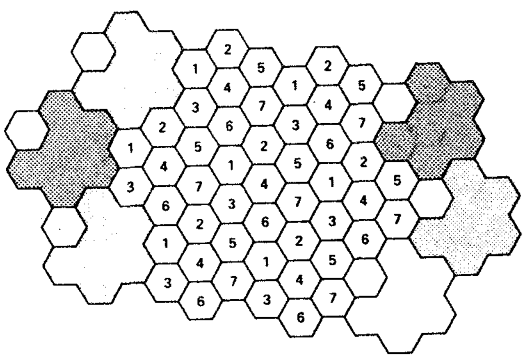
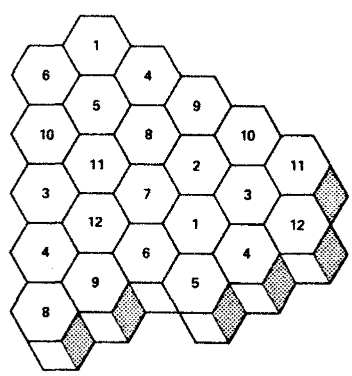


Fig. 6 (a) 7 cell repeating pattern.



(b) 12 cell repeating pattern.

The second alternative is for each cell to be sectored by using directional aerials which only cover one part of the cell. For example, three aerials with 120° each will cover one cell, using the same transmission frequencies, effectively tripling the number of channels which can be used and giving a corresponding increase in the number of possible users.

The two cellular communications systems in use in the UK, Cellnet and Vodafone, illustrate this well. Vodafone uses the seven-cell arrangement, but in urban areas has sectored each cell with three 120° directional aerials, which is about the limit of the system. Cellnet, on the other hand, has a 12-cell arrangement and so can sector its cells more thoroughly (with six 60° directional aerials in each cell) before reaching the system limits. After the sectoring limits are reached, further users can only be incorporated by splitting each cell into seven or 12 smaller cells.

Future Limits

However, there is a lower limit to cell size when splitting, which depends primarily on system accuracy and where the aerial can be sited. The smallest usable cell (in London, actually) is about 2 km in radius. Smaller than that and it becomes too critical to be able to site an aerial in a convenient position. It's impossible to site an aerial, say, smack in the middle of Tottenham Court Road if that's the ideal spot. Tolerances of a few hundred metres must be built-in to the system to allow convenient aerial siting, which inevitably would cause interference problems unless cell size is sufficiently great. So, in effect, there is a maximum limit to the number of users which can be accommodated on a system.

When the limit is reached will depend on the rate of growth of new users to a system. Eventually, however, the time must come when both existing cellular communications systems are choc-a-block and new systems will have to be built. Even then, unless far more frequency spectrum is allocated to cellular communications, it's not going to be the case that we'll all have our very own cellular telephone in the future — the wired 'phone will be with us for a long time yet!

And talking of the future, it is interesting to note that the UK TACS systems, Cellnet and Vodafone, are each licensed to use only 300 of the 1,000 channels allocated by the Government for present cellular communications purposes (21 of these are allocated for control data purposes, leaving 279 channels each). The remaining 400 are presently allocated for the Europe-wide second generation cellular communications system, planned for the 1990s.

The older mobile telephone services use HF and VHF transmissions which have unpredictable and long propagation ranges. Cellular communications systems, on the other hand, use UHF transmissions which are essentially line-of-sight (communications links can only take place up to a maximum of about 40 km and won't go any further than the horizon), and extremely directional, with highly predictable propagation ranges. Also, because UHF transmissions penetrate deeply into buildings, tunnels, and other physical barriers (unlike HF and VHF transmissions) lower power transmissions can be used, allowing ranges of only a few hundred metres or so. Radiotelephone services operating at HF and VHF must 'swamp' an area to provide the equivalent penetration, creating long propagation ranges.

For reference, the UK TACS cellular communications system uses transmisions at typical effective radiated power (ERP) levels of 50 to 1000 watts for base stations, and 0.6 watts to 10 watts for mobile equipment. The frequency band 935 to 960 MHz is used for 'forward direction' transmissions (from the base station to the mobile) and the band 890 to 915 MHz is used for the 'reverse direction' transmissions from the mobile to the base station).

Cell size is not fixed throughout the country, as you've probably gathered from this discussion already. In rural areas a cell can be quite large (up to 40 km in radius, as we've seen), while in urban areas cells are decidedly small. The general rule-of-thumb is that all cells should have about the same number of users and so have the same number of channels available for those users.

Over To You

The use of quite small cells in a cellular communications system leads to the problem which occurs when a mobile user leaves one cell and enters another. The problem is solved with the use of complex network switches which automatically switch the links through the best base station so that reception and transmission is maintained. The complete national system (Fig. 7) is based around these network switches, which route communications links in the first place and perform the functions of time-keeping and maintenance of tarrif data. Finally, the network switches monitor the position of all users so that any call to a mobile user will be quickly routed.

The process of switching from one base station to another when a mobile user goes from one cell to another (and indeed, from one sector of a cell to another) is known as 'hand-off'. This occurs in about 300ms so usually is undetected by the user. Individual cell base stations monitor each communications link in progress, and if communication quality falls below a predefined level the network switch is automatically alerted.

Base station monitoring is remarkably simple. Besides the channels available for telehone communication links, there are some channels reserved for control and signalling communications. The mobile equipment transmits control signals at regular intervals, but when actually in the process of a communications link, it also transmits a tone in a control channel. If the signal-to-noise ratio of the tone falls, indicating the user is moving out of the cell, the base station informs the nearest network switch. It is then up to the network switch to monitor signal strengths at all surrounding cell base stations and switch the link onto a different channel and base station.

Signal strength sensing of this type can also provide the mobile's position to the network switch, at least in terms of the base station which receives the strongest signal. This method of locating the mobile works best in the countryside where signal strength is usually dependent only on the mobile's distance from the base station. In an urban area signal strength sensing is not so useful. A mobile may produce a low signal strength even when comparatively close to a base station because it is being nulled by various fixed and mobile objects. Some cellular communications systems (not TACS) use an alternative form of positional sensing, called 'trilateration', in which the mobile regularly transmits pulses which are received by at least three base stations. The relative delays experienced by the base stations in receiving each pulse indicates the distance the mobile is away from each base station and so gives its position.

Network switches are connected directly to the PSTN so that any fixed telephone subscriber can call any mobile user, or vice versa, and any mobile user can call any other mobile user — world-wide.

Roaming

If a user moves throughout a cellular communications system roaming is said to occur. To roam right throughout the system means hand-off will at some time be required from one cell to another, where the cells belong to adjacent network switches. For this to happen, inter-switch hand-off is required, not just inter-cell hand-off as we've previously considered.

Interestingly, the Vodafone system has not yet got inter-switch hand-off (Cellnet has just been updated to incorporate it). However, Vodafone's network switches cover very large areas (each switch can accommodate more than 100,000 users, compared with Cellnet's 30,000 users) so the facility is not so critical.

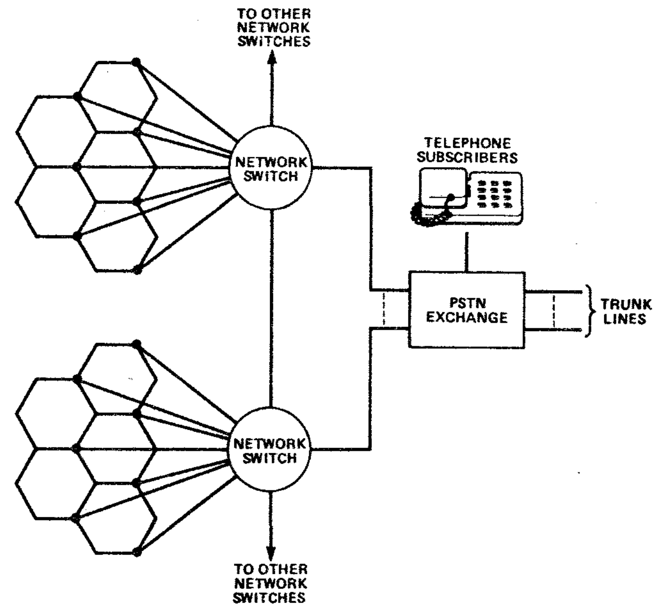


Fig. 7 Connection of cells to the public Switched Telephone Network through interconnected network switches.

Features

Now we've described the system, what can it do? First and foremost cellular communications provides a means whereby a mobile user, in a vehicle or on foot, can maintain telephone communication with whoever the user wishes to contact, or whoever wishes to contact the user. So all the features usually taken for granted with the 'phone are available wherever the user travels.

More than this, there are some features which the existing landline telephone network cannot usually provide. These extra features include:

- **Call diversion.** The incoming call can be assigned to an alternative number when the mobile is busy, turned off, or does not reply within a certain period.
- **Three party conference.** Board meetings over the 'phone. A conversation between three or more parties can be heard simultaneously by all parties.
- **Call transfer.** A call can be transferred to another telephone location by the mobile user.
- **Selective call barring.** Certain types of call, such as international calls, can be denied to the mobile user.
- **Alarm call.** The network switch will automatically call a mobile at a time programmed by the user.
- **Camp-on.** If the mobile is in use, an incoming call will be put 'on hold' at the network switch, until the mobile is free. At the same time, the mobile user will be warned a call is being held.
- **Call holding.** An existing call can be put on hold, by the mobile user, while a camped-on call is answered.

Most mobile equipment also has the following facilities:

- **On-hook dialling.** The handset can be left on its cradle until the called party answers.

Cellnet only

British Telecom Mobile Phone Division
Docos House
68–82 Commercial Road
London E1
Tel: (01) 432-6280
Caledonian Communications Ltd
17 Waterloo Place
Edinburgh
Scotland
Tel: (031) 558 1144
The Carphone Company
Vallis House
57 Vallis Road
Frome
Somerset
Tel: (0373) 73220
Cellcom Ltd
Sutherland House
70-78 The Broadway
London NW9
Tel: (01) 202 2322
Cellular One Ltd
114 Windmill Road
Brentford
Middlesex
Tel: (01) 568 1166
Granada Mobile Telephones
Dane Street Chambers
Dane Street
Bedford
Tel: (0234) 55233
Marconi Mobile Radio
Marconi Communications Systems Ltd
New Street
Chelmsford
Essex
Tel: (0245) 353221
Motorola Communications Services Ltd
Jay's Close
Viables Industrial Estate
Basingstoke
Hants
Tel: (0256) 58211
Relcom Communications Ltd
Hammersmith Industrial Estate
Winslow Road
London W6
Tel: (01) 741 8581
Securicor Robophone Communications Ltd
Ambassador House
Brigstock Road
Thornton Heath
Surrey
Tel: 9)1) 689 2144
Tactico Ltd
65 Logie Green Road
Edinburgh
Scotland
Tel: (031) 556 6167/8

Racal Vodaphone only

Advance Car Telephones
226 Christchurch Avenue
Kilburn
London NW6
Tel: (01) 328 6514
Automobile Association
AA Vodaphone
Fanum House
52 London Road
Twickenham
Middlesex
Tel: (01) 891 6191
ECT Cellular Ltd
14 Muswell Hill Road
Highgate
London N6
Tel: (01) 368 4321
Ericsson Information Systems Ltd
18 Clerkenwell Road London EC1
Tel: (01) 251 0187
In-Car Telephones
Unit 19
Acton Business Park
The Vale
Acton
London W3
Tel: (01) 749 9572
London Car Telephones Ltd
9 Lower Addiscombe Road
Croydon
Surrey CR0 6PQ
Tel: (01) 680 4444
Racal-Vodac Ltd
Freepost
Newbury
Berkshire RG13 1BR
Tel: (0653) 69000
Storno Ltd
110 Grafton Road
London NW5
Tel: (01) 267 5136
Thorn-Ericsson Ltd.
Viking House
Boundary Lane
Horsham
West Sussex
Tel: (0403) 64166

Both Cellnet and Racal-Vodaphone

AirCall PLC
108 Rochester Row
London SW1P 1JP
Tel: (01) 843 9000
Answercall Cellular Telephones PLC
23 Mount Street
London W1
Tel: (01) 499 2476
Cellcall Ltd
5 St Botolph Street
London EC3
Tel: (01) 283 1122
Digital Mobile Communications Ltd
Station House
Harrow Road
Wembley
Middlesex
Tel: (01) 903 7753
Europa Communications Ltd
Merevale House
Parkshot
Richmond
Surrey TW9 2HW
Tel: (01) 940 9433
Excell Communications Ltd
Excell House
Hale
Altrincham
Cheshire
Tel: (061) 941 7006
Gazelle Group PLC
Ponton road
London SW8 5BL
Tel: (01) 627 0000
International Communications Ltd
Unit 19
Commercial Way
Park Royal
London NW10 1YP
Tel: (01) 964 0065

- **Short code dialling.** Frequently called numbers can be stored and recalled using a code (generally two digits).
- **Electronic lock.** Prevents unauthorised use.
- **Received call indicator.** The equipment indicates a call has been received while the user has been away from the vehicle.
- **Hands free operation.** Conversation can take place without lifting the handset.
- **Last number redial.** The previously dialled number can be redialled, by pushing a single button.

Quality

Overall quality is pretty good. However, it relies mainly on the aerial the user has on the car. It's no good using a bent piece of coat hanger wire and expecting first class results. In a high signal area, with the vehicle stationary you'll have a successful call, but start to move, especially through fringe reception areas, and quality will be lousy. There's no doubt, an incorrect, or even a correct but incorrectly fitted aerial will give poor results.

Research carried out by laboratories, cellular operators, and aerial manufacturers has shown the best position for an aerial is on the roof of a vehicle. So, don't expect to be able to use your existing car radio aerial for cellular purposes. If you don't fancy the idea of defacing your brand new Ford Chevalier RS Turbo GX with an ugly brute of a roof aerial, then cellular communication is not for you.

There are alternatives such as an 'on-glass' aerial or an elevated feed aerial. Unless these are properly installed, you may find you've wasted an awful lot of money. Consult the professionals. That does not necessarily mean the people you obtain the mobile equipment from. Although they will usually only sell you the correct equipment for your needs, they may not be as technically aware of all the aerial considerations as they could be.

The Bottom Line

Finally, how much does all this cost? You can't get something for nothing in this world, and what you get out of your cellular communications telephone will depend on how much you put into it. The 'phones themselves will cost you anything from about £1,000 to £2,500 to buy and from £35 to £70 per month to lease, depending on facilities.

Running costs depend on which of the two systems and which features you use. Typical costs (after the initial connection) run at around £25 per month for rental of service, and around 33p per minute of daytime calls.

From these figures, you'll appreciate that cellular communications is presently a company luxury or a rich man's status symbol. If you're stinking rich or a mobile executive and you think you need easier communications to do your job better, cellular communications could be for you. As time goes on and costs come down (which they are bound to do as the market grows) ordinary consumers may be tempted. For us ordinary mortals my advice is to wait for a year and see what happens. Already, prices are falling.

Some of the data used in this article was taken from Cellular Communications 1986 — A Worldwide Report, produced by Mintel Productions Ltd, and is reproduced courtesy of Cellnet.

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