Radio Research Advisory Committee (RRAC)

The Strategy

First Annual report [Revision 2 - 17 Sept. 2001]

Executive summary:
The RRAC was set up to advise the Radiocommunications Agency on its research programme. In its first year the RRAC concluded that a strategy can be built around the four elements considered in this report covering (1) improvements in current use of spectrum, (2) sharing and coexistence studies, (3) spectrum efficiency issues, and (4) forward research and technology benefits, including extending the usable frequency range. These elements need to be underpinned by fundamental radio science and radio wave propagation data.

The strategy is a means of re-deploying existing research effort and expertise with new objectives and the RRAC provides the consensus for change by keeping apace of the convergence of regulatory policy issues and convergence of communications technology itself.

Within these topics the RRAC felt three sub-elements would apply: (1) directed research including "data, theory, measurement and modelling"; (2) people, programmes and institutions; (3) Collaboration, Industry and European dimension. Furthermore the RRAC believes that the highest priority should be given to accommodating new services whilst ensuring that the two ~~present~~ future significant ~~telecommunications~~ Telecommunications growth areas, namely Third -generation mobile (3G) & Broadband Wireless Access (BWA), are supported by the necessary research programmes. Although the Agency will focus on spectrum management, studies need to be compatible with Industry led research which tends to be short term, near market and technology or network specific.

Born out of the research review recommendations, the RRAC considers that this research strategy should put more emphasis on "spectrum efficiency" and link in with the RA Spectrum Strategy document. For most frequency bands the spectrum strategy outlines the ~~protection of existing~~ current services and future requirements and highlights where changes may be possible. This tries to indicate how the spectrum will be managed over the World Radio Conference (WRC) work process. Looking further ahead, the RRAC may identify key bands, or areas such as Broadcasting band re-alignment, increased use of higher frequency bands, where greater changes are needed. This in future will also need to meet the overall objectives of the unified regulatory body responsible for communications (OFCOM), expanding to cover the wider responsibilities of this organisation.

The four main short-to-medium term priorities are seen as:
1) Accommodating new services
2) Better use of existing spectrum.
3) Sharing studies (e.g. radar bands) and EMC issues.

4) Research exploiting use of higher frequencies, beyond present usage, as part of the formal research programme.

Key Recommendations to support the priorities:

- Coexistence studies and research topics including software controlled radio, sharing in Radar bands, and future requirements for Mobile services in 1 to 5 GHz bands.
- Collaborative research in the area of smart antennas.
- Develop metrics for spectrum efficiency.
- Research into higher usable frequency range for most services.
- Better use of existing spectrum with an emphasis on topics relating to network planning and network architecture to facilitate this.
- ~~Incentive spectrum pricing is seen as a mechanism to promote spectrum efficiency.~~
- A range of long-term (blue-sky) research areas for consideration with academic participation (allowing the researcher a wide degree of interpretation within the topic).
- The need in future to address evaluation and control with a few individual project proposals.
- The need to encourage the technical Task Group activity, particularly in propagation research and to build on multi-diciplinary expert groups.

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1.0 Introduction

The Radio Research Advisory Committee (RRAC) provides a national forum to assist the Radiocommunications Agency (RA) in formulating its radio research strategy and obtain advice on research related issues. It is important for Government and for the UK to plan a cohesive spectrum strategy and the RRAC recognises that a research strategy is a means of helping to deliver this.

The Agency has a spectrum strategy and publishes a "strategy for the future use of the radio spectrum in the UK". It is in the process of reviewing its research strategy (currently based on internal and external research programmes covering propagation, Electro Magnetic Compatibility (EMC), Mathematical programme, sharing studies, and other technology areas.) The current intention is to integrate the research strategy more closely with the RA's spectrum strategy.

The key role of the RRAC is to advise the RA on its research programme and related issues. It provides a top-down view to help to develop the research strategy for the RA. The Radiocommunications Agency has the task of managing the civil radio spectrum and implementing policy relating to spectrum management and spectrum efficiency. The term research is used here to cover just the technical aspects of frequency management.

Three Task Groups (TG's) report to the RRAC covering Fixed, Mobile, HF propagation research and associated radio technology. These Task Groups provide detailed technical support and research knowledge that is disseminated to the wider radiocommunications community including the space science community.

[The RRAC recognises the excellent skill base in propagation research at Rutherford Appleton Laboratory (RAL) and do believe it is necessary to widen these skills in line with the changing market and technologies (with its potential to form a European centre of excellence).]

As well as proposing a strategic view on research in this area the RRAC will further recommended a method to evaluate research projects and recognises the work of economics in defining, implementing, and measuring the benefit of individual research projects.

The RRAC has also sought the wider views of "Corresponding members" which are simply those interested parties involved in Radiocommunications research, industry and use of the radio spectrum. An Open Forum meeting is scheduled in November 2001 to allow more inclusive views from the Radiocommunications industry and users to be considered.

The government recently announced as part of its communications policy the intention to have one regulatory body covering all electronic communication. This can be seen as the convergence of the regulatory organisations into an Office of Communications (OFCOM) that will be independent of Government, but with strong links to Government departments. From a frequency management viewpoint this brings together, communications, broadcasting and content standards in one organisation with responsibility for all users of the radio spectrum.

Recently the Government published this policy in its Communications White Paper: A New Future for Communications - Guide to Spectrum Issues. The main highlights are as follows:

- Importance of spectrum and convergence scenarios
- Innovative spectrum management

- Use made of market-based tools
- Spectrum management review
- Spectrum pricing for broadcasters - importance of spectrum efficiency, broadcasting spectrum to be valued but no early change to basis of charging broadcasters for spectrum
- Reaffirm commitment to spectrum trading, subject to European Union (EU) negotiations

2.0 Committee structure

The RRAC operates through a small executive committee comprising of individuals selected as technical experts in their own right covering a range of service, communication, and radio science areas. This broad range of experts can advise and where necessary draw on other resources to provide top level guidance. It is recognised that the committee will need to keep the wider community informed and it intends to promote wider consultation through open forum, presentations, and direct submissions. It is the intention to publish some documents on the RRAC Web site and to assist in disseminating research data. The committee has for example visited facilities such as Rutherford Appleton Laboratory (RAL) and Radio Technology Compatibility Group (RTCG), Whyteleafe, to get an overview of existing research and laboratory projects. The RRAC intends to consult other research centres of excellence over the next twelve months and hold meetings with significant industry representative bodies in both radio service and manufacturing sectors.

2.1 Terms of Reference

The RRAC plays a key role by advising the Agency on the formulation of RA policy in relation to the Research Programme and the research related aspects of the Spectrum Efficiency Scheme (SES). The committee meets 4 times a year and technical Task Groups (TG's) on Fixed, Mobile and HF service issues report their progress to the RRAC once a year. The terms of reference are shown in Annex 1.

2.2 Composition of the Committee

The RRAC has an independent chairman and members from Industry, Universities and the RA. (A list of members is shown in Annex 2.)

3.0 The Issues

3.1 Sharing / coexistence requirements on a frequency band/service basis

As a consequence of the increased pressure on the use of spectrum there is a much greater need to share services, so sharing studies have been an important research topic in itself.

On this issue ~~The main theme that~~ the RRAC would like to stress the importance of ~~convey is the need for~~ coexistence studies. The RRAC intend to continuously monitor both Committee of European Post & Telecommunications (CEPT) and International Telecommunications Union (ITU) based coexistence study groups to ensure there is no overlap with any UK based research/study programme. This will ensure the UK benefits from extensive work already completed or in progress within these groups.

With the convergence of technology (individual service to system requirements) a block of frequencies with defined coexistence parameters may be more appropriate. The current concept

of allocation of frequency to a particular service needs to be developed into spectrum for system specific applications with diverse use (these may be frequency agile, varying with information rate). In the near term and in the future there will be a greater need for both conventional sharing and more futuristic coexistence requirements.

Grades of service in the future are likely to vary from a "best endeavours" approach to very high levels of circuit availability requirements and there may be many occasions, be it on a geographical, regional or national basis, when a mixture of services could coexist. The advent of broadband fixed wireless applications is typical of future demands on existing spectrum. Establishing a policy at an early stage, based on sound research analysis, will facilitate a successful roll-out of such networks. A research project on measurement of and interference due to Ultra Wide Band (UWB) has been started however, the RRAC felt this topic merited greater emphasis.

It is considered important to focus some research on the trends arising from future WRC agenda items, ITU Study Groups and aspects of European Union directives relating to communications. For WRC-03 and 06 there are specific sharing issues and also some of a more general nature. Some specific ~~The more general~~ technology areas include Navigation/location (e.g. Galileo), High Altitude Platforms (HAPs), Little-Low Earth Orbit (LEO) satellite requirements, and Harmonised spectrum for Mobile (with frequency agile techniques), along with general radio science may be significant in terms of future research.

[Editorial note: definition of radio science added in glossary.]

There is currently a wide range of practical measurements and research data from Laboratories such as RTCG that is fed into the CEPT project work in support of sharing studies and related standardisation activity at an international level.

[The RRAC recommends the following research topics and coexistence studies be considered further:

- ***The implications of software controlled radio.***
- ***Further develop the approach for potential sharing in Radar bands.***
- ***The requirement for Mobile in the 1 to 5GHz band and the need for use of higher bands.]***

3.2 Spectrum efficiency research policy

The RA has promoted spectrum efficiency over a period of time and elements of this now form a fundamental part of the research objectives. The RRAC has taken a top-down approach to the research policy and aims to link this closely to the RA Spectrum Strategy document.

The RRAC will advise on the research element of spectrum efficiency and to a lesser extent on Refarming policy. The steer from the RRAC regarding the research element of the spectrum efficiency scheme is intended to link industry, academia and government in some long-term research proposals. This includes European collaborative projects and projects such as “smart antennas”, and may tie in with the “Virtual centre of excellence” and the “multi-disciplinary team” approach.

[The RRAC recommends pursuing the potential for collaboration on research (e.g. smart antennas) and in the longer-term greater involvement in spectrum efficiency collaborative programmes.]

3.2.1 Research on spectrum efficiency

For the mechanisms of spectrum pricing to be implemented in an effective way, it is important to establish the required metrics to determine spectrum occupancy and use. The overall aim of this research topic would be to establish a set of metrics for spectral efficiency. A key dimension that needs to be included is the interaction of frequency band and service type. The metrics need to reflect quality of service (QoS) aspects and cost (operator costs, network use/cost etc).

The mechanism should also be able to predict the practical maximum capacity of a particular frequency band, along with the current use and future demand figures.

Candidate metrics would include *throughput* (bits/sec/Hz or bits/sec/Hz/km^2) or numbers of users (max and average simultaneous users/MHz/ km^2). For some services *traffic flow* (Erlangs/Hz or Erlangs/Hz/km^2) might be used as a measure of information rate. The "trade off" can then be made between, 1) information rate, 2) QoS, 3) cost and 4) time to full occupancy. Following on from the identification of the metrics, there is then a requirement for identifying the technology developments that show improvements in spectrum efficiency.

[The RRAC recommends research projects on metrics for spectrum efficiency be established early in the research programme. This should provide a benchmark for specific frequency bands and services on which spectrum efficiency can be based.]

3.3 Antennas

Antenna elements continue to be extensively researched internationally in industry and universities to satisfy demands for increased bandwidth, higher frequency operation, improved polarisation and radiation pattern characteristics, together with operationally robust features at low cost. The development of new materials also contributes to advances in antenna construction and manufacture. This world-wide attention to antenna elements is an important contribution to spectrum efficiency and it is recommended that the RA maintains awareness of the advances and availability of improved hardware.

Research on antenna arrays is increasingly dominated by the embodiment of digital signal processing techniques and is internationally widespread. The generic term for this combination is 'adaptive antenna' but other terms below have been latterly introduced suggesting intelligent behaviour. Large phased arrays with rapid beamforming facilities, controlled degradation and operational robustness are almost exclusive to defence applications and are very high cost installations.

In recent years smaller versions of these adaptive antennas have been successfully deployed by base station antenna designers as a means of reducing interference sources by the creation of beam nulls. This in turn has led to the conception of space-time coded multi-antenna wireless systems (known as multiple-in, multiple-out or MIMO) whose capacity can exceed those of conventional wireless systems by an order of magnitude or more. Furthermore, MIMO's show

the greatest advantage in the absence of line-of-sight and in situations of severe multipath which is remarkable. Research activity is now intense and the term 'smart antenna' is generally associated with these recent developments. Most of the investigations to date are confined to the computer simulation of these systems based on assumed channel characteristics and the algorithms developed are relevant only to the latter. The recently emerging 'software antenna' concept provides for a library of algorithms, to match differing specified channel characteristics and thus extends the adaptivity of the antenna system.

Smart antennas can in principle make an immense contribution to spectrum efficiency and it is recommended that the RA plays a central role in identifying gaps in international research and its dissemination to UK spectrum users. The simulation research to date has greatly raised expectations but in reality, the algorithms must precisely relate to the channels of interest. Obtaining *a priori* data on a channel invokes extensive measurement, processing and mobile trial work and is necessarily time consuming and expensive. More research on training algorithms and self-adaptive learning processes is needed to realise the practical potential of these new concepts at an acceptable cost.

[The RRAC recommended that the RA include some smart antenna research, possibly in the field of steerable antenna for broad band usage, in its strategy if the UK is to keep abreast of this work. However a detailed vetting of present research programmes should be undertaken if the UK is to avoid duplication of related projects within Europe.]

[In particular the RRAC proposed smart antenna research on training algorithms and self-adaptive learning processes is needed to realise the practical potential of these new concepts at an acceptable cost.]

3.4 Reallocation of services to other bands

The RRAC has highlighted the need for more access to spectrum for new systems, particularly mobile type services. This may be accommodated by greater sharing (see section 3.1) and by trying to free up spectrum with new technical solutions requiring less bandwidth (e.g. Digital systems, new spectrally efficient radar, release of some spectrum used by Military or Government). However, this might also be facilitated by techniques such as a change to the "delivery of broadcasting" from terrestrial transmitters to satellite/HAPs delivery so freeing up terrestrial bands for new systems.

There is also a strong need for research into the highest usable frequency range by particular radio services with the scope to explore the use of higher frequency bands. It is key to establish the suitability of frequency bands of 70 GHz and above for particular services.

[The RRAC recommends a technology review project be established to determine potential timescales for the implementation of new technology that would allow reallocation of services to higher frequency bands.]

3.5 Better use of existing spectrum

The RRAC has highlighted some areas where potentially "better use" of the existing spectrum could be made and has proposed research areas including Technology, Planning, and Network architecture. Some aspects may be suited to commercial research.

The *Technology* research area included software defined radio, and smart antennas.
The RRAC proposed that research into coding schemes could be covered by other commercial and academic research projects.

The network *planning* aspects of research include analysis of the impact of ATPC, interaction of different networks, etc. Work needs to be done on analysing the variation of frequency re-use factor for different services and how this impacts on co-ordination and sharing studies.
It was felt by the RRAC that commercial companies were more inclined to study coverage predictions in existing frequency bands, propagation modelling (interference and wanted paths) where existing data is available, network availability, and site shielding.

The network *architecture* aspects of research include the efficiency of mesh networks (Point-to-Multipoint (P-MP) and Point-to-Point (P-P) networks) and "Network Interoperability" covering "Ad hoc networks" and Adaptive networks. The aim is to enhance the commercial operation of the network to increase spectral efficiency (by accommodating multiple operator use and geographic reuse).

The RA has ongoing research projects relating to benchmarking man-made background noise and research into EMC controls, as part of the policy to keep the spectrum clean and to make better use of existing spectrum.

[The RRAC acknowledges that some technology areas are covered in their recommendations, however the thrust of the research will need to address the network interoperability and architecture aspects of radio systems. It is therefore recommended that an initial project study should be defined with operator support.]

3.5.1 Spectrum efficiency and technology

There are a variety of spectrum efficiency applications where technology can offer solutions. The RRAC may consider the establishment of a project to assess specific technologies in terms of spectrum efficiency.

The concept of specifying a particular technology for a particular frequency band is constrained as it may well effect competition and International agreements. However, where a technology is demonstrably more spectrally efficient than another, the RA does have control of spectrum pricing measures, and a low cost access to a band can be encouraged in some cases.

~~3.5.1.1 Incentive spectrum pricing~~

~~Spectrum pricing is the charging of licence fees for access to the radio spectrum to reflect the value of spectrum based on specific management objectives and legal requirements. These objectives may include items such as the efficient use of spectrum and the reduction of hoarding.~~

~~Spectrum pricing now applies to the vast majority of licensed services and sectors using the radio spectrum except for a few cases where the pricing tool was marginal or not appropriate.~~

~~Although the RRAC terms of reference do not specifically cover this area, the application of spectrum pricing to bands with "congestion" and certain band sharing situations is important and touches on the technology requirements. New technology and convergence of services may require a research strategy which promotes new technical systems, coupled with incentives in the form of spectrum pricing to drive this forward.~~

~~One key aspect for the UK and European communications market relates to the "network interoperability" issue that is largely driven by economic aspects. Government policy to promote networks sharing and connectivity needs to be explored.~~

~~[The RRAC recommends the promoting of network sharing through economic and technical solutions.]~~

3.5.1.2 Spectrum trading

Spectrum trading is the ability to re-trade part or the entire spectrum pertaining to one licence-holder. Although this may be a consequence of spectrum pricing, this mechanism is seen as a method to reduce spectrum hoarding and allow greater market flexibility for spectrum (akin to property rights). The RA is currently examining the policy and the framework required to enact related legislation.

3.6 Forward research issues

The RRAC has identified several areas of long term "forward looking" research where the strategic aim is to stimulate the development of new technology by access to spectrum or new system operational parameters. This research lends itself well to SES funding and is seen as collaborative and "pre-competitive".

There are three categories for the future research:

1) New Technology, covering software (software defined radio (SDR), filtering) and hardware, (Frequency Selective Structures (FSS), smart antenna, micro-satellites).

2) New delivery mechanisms/Refarming
(Fibre, HAPs, Satellite, freespace optical links)

3) Studies – new propagation scenarios, convergence, Digital, UWB,

They can be further subdivided:

<u>Spectrum efficiency</u>

This is examining areas such as wideband technology, antenna technology, and EMC aspects to keep the spectrum clean. The type of projects that are envisaged include:

- Ultra wide band technology
- Multipath, multi-antenna systems
- Filtering, software and hardware

- Manmade background noise
- Radio system simulation - Tools to simulate radio environment and the dynamics of adding new radio services.
- Threats to spectrum efficiency in terms of noise floor and new systems etc.

Studies/Theory

This research area examines theoretical modelling and potential sharing characteristics of existing and new systems. The type of projects that are envisaged include:

- Software, and smart agents.
- Maximum usable propagation frequency for environments (e.g. dense urban, suburban).
- Spectral sharing for very high user rates (>>2 MB/s)
- Impact of fibre networks and ADSL and optical links on radio spectrum. (Also "microwave over fibre")
- Broadcast delivery by satellite or fibre, with refarming implications.
- Network interoperability and connectivity: Optimisation of Base station deployment for mobile multimedia. Including "Ad hoc connectivity", home networks to urban networks.]
- Effects of IP delivery on spectrum efficiency
- Broadcast radio return and VSAT systems

Convergence

This area ties together the convergence of communications technology along with the convergence of some regulatory aspects of spectrum management.

- PMR/SMR will be a subset of wide-area cellular networks.
- MSS future requirements for spectrum and system performance
- QoS with respect to off peak vs peak delivery, bit rates, data-loading and re-routing.
- Pico-cell, micro-cell, and Multi-cell systems, and location (Global, regional and local positioning)]

[The RRAC recommends that research projects in several of the above areas be started now for "longer -term" research benefit. This would be implemented through academic projects (PhD studentships- 3 years) and possibly collaborative work with RAL.]

[We need to prioritise a few.]

3.7 Remote monitoring & control techniques

Remote monitoring of radio networks for frequency selection and network management aspects may need to be developed. The Agency currently carries out monitoring to ascertain information on spectrum use and to make measurements in order to resolve problems of interference. In the future the RA plans to have more details of spectrum occupancy on its database, which may reduce the need for some continuous monitoring activities. It is foreseen that future equipment will have software and hardware dynamic control, with the ability to detect channel loading and make dynamic decisions on channel reuse.

Within the RA research programme there are projects examining the measurement of low level wide band noise and its effects on systems. Future research will need to focus on the "regulatory aspects of dynamic allocation" and appropriate standardised control algorithms. In addition longer-term research should examine "frequency agile" systems, network monitoring and control techniques.

[The RRAC recommends the following research topics and studies be considered further:
- ***LEO satellite systems and data hand over***
- ***Related aspects of ad hoc networks and capacity sharing over networks.***
- ***Automatic detection/logging of illegal use of spectrum.]***

3.8 Propagation

Propagation research has been a key activity over the years to provide data, measurements and predictions of radio and ITU-R propagation standards. The field of propagation research is particularly important for a wide range of research projects and has been seen as underpinning a range of technical research projects. The bulk of the Agency propagation research work is contracted to RAL; however, the RA has decided that future studies will be individual research contracts let by competitive tender. The three technical Task Groups (TG's) have identified particular propagation research topics that require research as well as some internal sharing research requirements (driven by CEPT, ITU-R, and WRC agenda items).

In accepting that possibly the majority of research projects are likely to involve some propagation study, the RRAC has not recommended that this in itself forms a specific research element. The proposed four research elements ensure that a strong focus remains on the prime objectives of maximising the utilisation of existing allocations and planning for optimum spectrum efficiency.

The RRAC accepts that RAL(RCRU) are clearly a centre of excellence on propagation issues and would recommend that they promote these skills on a European wide basis. It is accepted that RCRU have made considerable progress in the redeployment of their excellent skill base to cover wider aspects of communications research. This should ensure that they fit well with the RRAC research strategy proposals. However pure propagation projects would not be excluded.

[The RRAC recommends the Task Groups maintain their autonomy and be encouraged to expand to cover new service related themes or multidisciplinary research areas. It is recognised that propagation research will underpin the range of TG activities.]

or

[The RRAC recommends that the TG's be realigned (Move away from "service" defined groups to "themes") (spectrum efficiency, Sharing & coexistence studies, forward research/higher frequency bands etc)]

4.0 The Priorities

This is based on the above issues but for the short and short/medium term ~~only~~.

1) Accommodating new services

2) Better use of existing spectrum.
3) Sharing studies (e.g. radar bands) and EMC issues.
4) Research exploiting use of higher frequencies, beyond present usage.

[The RRAC recommends the RA base its research spend on these priorities.]

5.0 The Benefits

The potential benefits have been identified on a short, medium, long-term basis. The present RRAC strategy is based on the next six (6) years however the specific benefits are detailed below.

Within the four topics the RRAC has recognised the importance of timescale to implement research projects and the need to establish early on, the potential time to benefit of particular topics. Generally the improvement of short-term usage of spectrum is seen as short term [6 month to 2 years] while sharing/coexistence studies mature in the medium term [2-5 year timeframe]. The topic of forward research technology benefits is seen as long term [5-10+ years] and the topic of "Spectrum Efficiency" straddles the medium to long term timeframe.

Short term benefits:
The research aspects of improved short-term usage are seen to offer improved access to spectrum and greater sharing of existing frequency bands. Flexibility in terms of time-sharing and improvements to inter-operational aspects of services and networks may be targeted.

Medium term benefits:
The output from research into spectrum efficiency and Coexistence of new and existing services is seen as offering benefits primarily in the medium term. New digital technology and wideband technology may enhance spectrum efficiency, while coexistence studies into the information rate requirements of "converged" services is a key issue in terms of sharing spectrum.

Long term benefits:
Stimulating new technology for potential improvements in spectrum efficiency is the main driver behind forward research benefits. Adding the capability of new applications combined with convergence, (delivery of high data-rate over short distance, location information, and interoperability of networks, Software Defined Radio). To stimulate these benefits, new propagation research and measurement work would be required in the medium to long term. However, to achieve these benefits the RRAC has expressed their concern as to whether the RA's manpower resource is adequate to mange the likely level of projects.

[The RRAC recommends the balance between short, medium and long-term research be apportioned in terms of financial spend in the approximate ratio 50%;30%;20%.]

6.0 The Economic return

The Economic drivers are seen to be outside the scope of the RRAC, but there are policy objectives to maximise the economic benefits from the radio spectrum. To realise these objectives, pricing is used as one of the control mechanisms to manage the spectrum and increase spectrum efficiency. There is a link in terms of economic drivers being part of the justification for sharing studies and the Mathematical programme mentioned in section 9.

It is recognised that the RA's Economic and Statistics unit covers the economic benefit and economic return aspects of spectrum management. For specific research topics the potential value needs to be evaluated (technical solution, time to benefit, implementation,).
It is important to be able to determine the cost benefits of research and advantages of introducing new services and the “value for money” of completed research projects.

[The RRAC recognises the economic drivers behind spectrum management and spectrum efficiency schemes. It recognises that this should be part of the initial project proposal and evaluation criteria.]

7.0 Project evaluation and review

The RRAC was asked to consider mechanisms for research evaluation and to make proposals on evaluation methods. As an example the RRAC has concentrated on two current RA managed research projects (Frequency Selective Surfaces and sleet propagation) and had presentations on these. As part of the evaluation process these examples have been assessed in terms of:
[Quality of work
Long term potential of research,
cost benefit.]
There is a general view that monitoring of research projects needs to be undertaken more frequently. This may require use of user requirement/definition, literature search & collaboration potential, risk/benefit assessment?]

In the future the aim would be to evaluate all RA projects with an agreed review methodology. [The RRAC proposed a project evaluation method in the form of ……..]

[The RRAC will be proposing better methods of project evaluation and it is felt that this should be used to strengthen the RA project management and it will also be necessary to revise the operation of the RA Technical Forum.]

8.0 Research Co-ordination

The RRAC recommends that there be a better cross referencing to other European and worldwide research programmes to prevent duplication and also to consider co-operations where either a timescale benefit or cost efficiency can be achieved.

There is greater potential for collaboration at an "International", "European" and "National" level. Here the concept of focal point in the form of a "virtual centre of excellence" or muti-disciplinary project approach could be developed. (RAL could play a key role in this function.)

[In making the following recommendations the RRAC would advise the RA to hold regular meetings with key members of RA staff, TG Chairman etc, who are participating in CEPT & ITU groups where their activities could help to formulate research projects.
The need for stronger collaboration is recognised and also came out of the research review recommendations. The RRAC proposes the RA set up internally a "fact-finding project" to track the status of EC, COST, and other collaborative projects in the field of radiocommunications.]

9.0 Review of present Research Projects

The reporting once a year of the TG activities for propagation projects is seen as an adequate review process. It is recognised these activities work well in an informal expert group with representatives from Academia, Operators and Regulators. It is recognised that the fluidity will allow for change as new systems are developed requiring a range of research activities.

Other projects will probably have been reviewed directly by the RA project manager. [The RRAC has recommended a review and evaluation process to try to improve the assessment and focus of individual projects.]

TG on Mobile and terrestrial propagation:
Key activities include database of diffraction path measurements, proposals for 3-D "street level" building database, and information on accuracy of propagation models. Future areas for consideration are 3G mobile and broadband FWA.

TG on Fixed service propagation:
Key activities include Fixed service outage (precipitation and year to year variability), modelling as applied to RA planning tools, and ITU-R standards. Future areas for consideration are application of rain and sleet statistics in UK planning and the inclusion of work on point to area Broadband FWA.

TG on HF propagation and ionospheric effects:
Key activities include collaborative and international study programmes on related aspects of ionospheric propagation. Updating the report on "Current UK Research into HF systems, HF propagation and the Ionosphere". Future areas of work include contributions to COST-271 programme and to act as a forum for this research area.

Summary reports from the Chairmen of each Task Group are attached in Annex 3 to this report.

RA Project review:
1) Propagation
Here the bulk of the propagation work is in the 3GHz to 100GHz range and is aimed at 2 to 5 year project cycles timescales. The bulk of the work is carried out by RAL however, but future

studies will be individual research contracts let by competitive tender. [Reviewed by TG and publication].

2) EMC
Participation in CISPR and ETSI standards bodies is significant and research information can be fed back into these organisations. (I.e. indirect peer review). The work is generally medium term (2-3 years).

3) Sharing studies
The majorities of the sharing studies are aimed at compatibility between new and existing services, and are driven by CEPT and WRC requirements. Although the WRC is held typically on a three-year cycle, Sharing studies are often required to be completed on a 2-3 month timescale for input into CEPT Working Party meetings for agreement. Reviewed and published as contributions to CEPT project teams and ITU-R work on sharing.

4) Mathematical programme
The drivers here have been spectrum efficiency, best-use and best practice, and economic value of spectrum. Various Universities and academic teams carry out this research. [Reviewed in terms of publications, longer term cost-benefit analysis.]

5) Other research areas
Quantifying the system parameters and anticipating the spectrum requirements are aspects along with EMC and compatibility issues. [This includes projects such as DSL systems and potential interference to radio services]. Some funding is provided in support of measurement techniques relating to radiological hazards.
[Tends to be reviewed in terms of user or policy requirements being met in the future.]

[The RRAC has recommended a review and evaluation process to try to improve the assessment and focus of the present mix of individual projects managed by the RA. Future projects will be assessed in relation to the four research criteria that form the research strategy.]

10.0 Implications for future Research programme

The RRAC has reviewed the research needs of the RA and the wider research needs as they relate to industry and academia and radio users.

The RA sees its future priorities as research in direct support of its regulatory functions. Research is often in support of international and national activities relating to the allocation of spectrum, and this leads to a primary focus on sharing studies that include co-existence and compatibility studies, and also the related aspects of EMC and keeping the spectrum clean. The next priority is research into new technology that helps to address spectrum efficiency requirements in existing frequency bands and also the exploitation of higher frequency bands with attendant propagation measurements. A third priority is the dynamic monitoring of spectrum use and the regulatory impact of software radio.

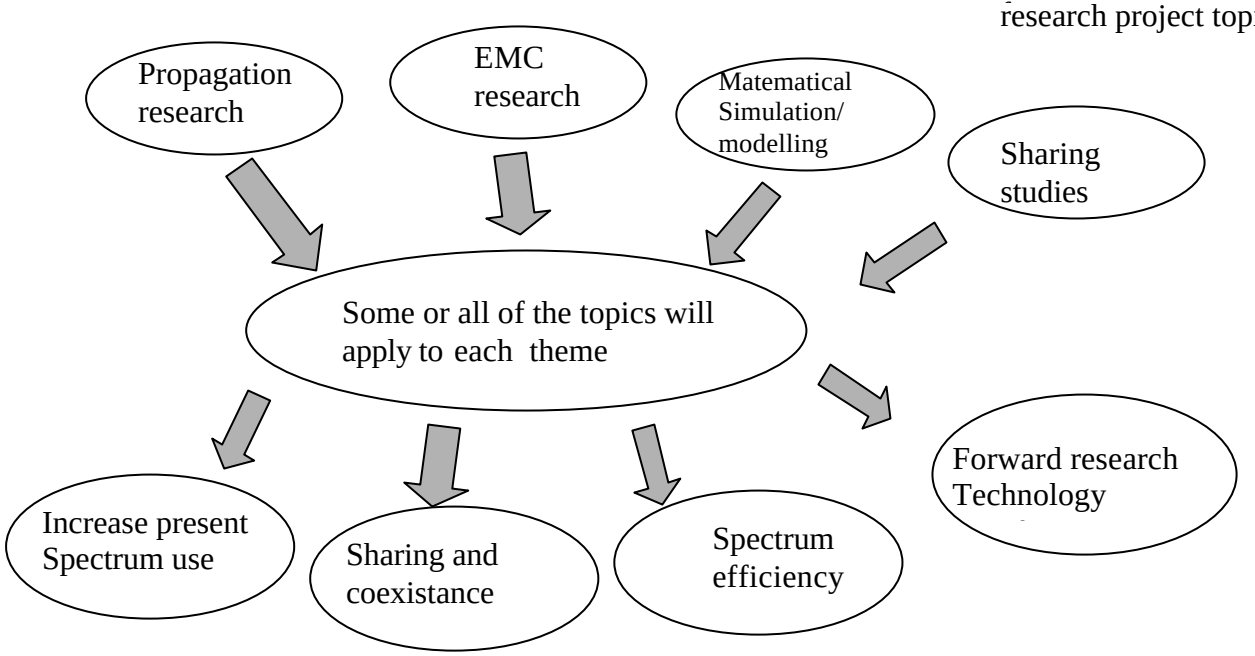
A fourth priority addresses longer-term (pre-competitive) research that may offer improved spectrum use, greater efficiency or stimulate development of new technology.

The RRAC proposes that industry should lead on the development of mobile communication technology with government commenting on ways to release more spectrum especially in bands above 3 GHz. There is a need to make use of the higher frequency bands for Fixed and Broadcasting services and collaboration within the EU may be addressed in these areas under the broad objective of making better use of higher frequency bands.

[The RRAC has recommended four priorities for the research work and a mechanism of assessment. The areas of collaboration ~~and a National focus for radiocommunications~~ is seen as important.]

New Strategic Research Approach

The past definitions
research project topics



Strategic Theme approach

11.0 Conclusion

The RRAC concluded that such a strategy can be built around the four themes considered in the report (1) improvements in current use of spectrum, (2) Sharing and coexistence studies, (3) Spectrum efficiency issues, and (4) forward research and technology benefits, including extending the usable frequency range.
[Furthermore the RRAC believes that the highest priority should be given to accommodating new services.]

The four main work priorities are seen as:
1) Accommodating new services
2) Better use of existing spectrum
3) Sharing studies (e.g. radar bands) and EMC issues.
4) Research exploiting use of higher frequencies, beyond present usage.

Key Recommendations to support the priorities:
- Coexistence studies and research topics including software controlled radio, sharing in Radar bands, and future requirements for Mobile services in 1 to 5 GHz bands.
- Collaborative research in the area of smart antennas.
- Develop metrics for spectrum efficiency.
- Research into higher usable frequency range for most services.
- Better use of existing spectrum with an emphasis on topics relating to network planning and network architecture to facilitate this.
- ~~Incentive spectrum pricing is seen as a mechanism to promote spectrum efficiency~~.
- A range of long-term (blue-sky) research areas for consideration with academic participation.
- The need in future to address monitoring and control with a few individual project proposals.
- The need to encourage the Technical Task Group activity, particularly in propagation research and to build on multi-diciplinary expert groups.

GLOSSARY and Acronyms

3G Third Generation (Mobile services)
ATPC Automatic Transmitter Power Control
BWA and BFWA Broadband Wireless Access & Broadband Fixed Wireless Access
CEPT Committee of European Post & Telecommunications
CISPR International Special Committee on Radio Interference
Coexistence studies Technical compatibility work to determine the parameters for two or more systems to share and operate in the same band and/or neighbouring bands. This includes co-channel sharing and adjacent band compatibility of both systems of the same service type and other radio services.
COST European research programme (COoperation in Science & Technology)
DERA Defence Evaluation Research Agency
DSL Digital Subscriber Line
EC IST European Commission, Industry Science & Technology research programme
EU European Union
EMC Electromagmetic Compatibility
ETSI European Technical Standards Institution
FSS Frequency Selective Structures (Materials with the characteristic of attenuating specific frequencies.)
HAP High Altitude Platform
IP Internet Protocol
LEO Low Earth Orbit (Satellite system)
Mathematical Modelling This refers to the application of mathematical theory, equations, and algorithms to predict, simulate, and optimise a solution to areas of frequency planning, decision making and efficient use of a resource.
Mathematical Programme Within the RA's Research Programme there are currently a set of projects relating to mathematical simulation techniques & modelling that can be applied to spectrum management, economic benefit, and decision analysis.
MIMO Multiple-in, multiple out (Smart antenna technology.)
MSS Mobile Satellite Service
OFCOM (Office of Communication) A unified regulatory body (non-governmental) covering communications, broadcasting and content, to be set up encompassing Oftel, Radio Authority, Independent Television Commission (ITC), Broadcasting Standards Commission (BSC), Radiocommunications Agency (RA).
P-MP Point-to-Multi-point
P-P Point-to-Point
PLT Power Line Technology
PMR Private Mobile Radio
QoS Quality of Service
RA Radiocommunications Agency
RAL Rutherford Appleton Laboratory
RCRU Radio Communications Research Unit based at RAL
Radio science relates to scientific diciplines where radio techniques are used to detect or measure specific physical or natural characteristics
Reallocation This term is used to describe the general option of reassigning frequency bands to currently unused or new frequency bands or for refarming purposes.

Refarming This term is used to describe the reassigning of frequencies within a band or existing allocation to new or existing services.

Research Programme This refers to the collective set of research projects consisting of five main categories (Propagation, EMC, Sharing Studies, Mathematical Programme, and Other technologies).

RRAC Radio Research Advisory Committee

RTCG Radio Technology & Compatibility Group (The RA's radio laboratory.)

SES Spectrum Efficiency Scheme (A grant aimed at improving spectral use and occupancy.)

SDR Software Defined Radio

Sharing studies Calculations to determine the parameters and potential for two or more radio services to share a frequency band (allocation).

SMR Short-range Mobile Radio

TG Task Group (A technical committee with representatives from Industry, operators, regulators and academia). Currently three TG's covering, Mobile, Fixed and High Frequency (HF) related research and radio science issues.

TWP Technical Working Party (Now superseded by term TG)

UWB Ultra Wide Band

VCE Virtual Centre of Excellence

WRC World Radio Conference is held approximately every three years and is organised by the ITU-R (International Telecommunications Union – Radiocommunications (Bureau).

Annex 1
[The full terms of reference are in document RRAC(00)04 on the "RRAC page" of the RA Web site http:www.radio.gov.uk/topics/research/rrac.minutes/minutes.htm]

Radio Research Advisory Committee

TERMS OF REFERENCE

1. Scope

The Radio Research Advisory Committee (RRAC) provides a National forum for the Radiocommunications Agency to formulate its research strategy and obtain advice on research related issues. The RRAC plays a central role in formulating Agency policy in relation to the Research Programme and the research related aspects of the Spectrum Efficiency Scheme.

The committee meets 4 times a year. In addition, there is an annual forum, which provides an opportunity for wider participation. One meeting each year reviews the activities of the RRAC Task Groups. All Task Group chairmen attend the review meeting; attendance at other meetings is by invitation from the RRAC Chairman.

2. Membership

There are two classes of membership, executive members and corresponding members. Executive membership, to attend RRAC meetings, is by invitation from the Agency. Appointment is for 2 year fixed term with the possibility of an extension. Representation is kept under regular review. Corresponding members have access to committee papers on the Agency web site and send in their comments by e-mail.

The Agency reflects the views of other government departments and the wider radio community at RRAC meetings. This includes the views of corresponding members and any views on research expressed at other Agency consultative committees and the regional customer panels.

The secretariat for the RRAC is provided by the Agency.

3. Task Groups

The RRAC may establish Task Groups on defined topics where there is value in bringing together a number of interests in order to develop and co-ordinate research activities.

The continued operation of task groups is kept under review by the RRAC.

4. Reports

The RRAC produces an annual report to the Agency Chief Executive. Chairmen of RRAC Task Groups submit annual reports to the RRAC.

5. Research Programme

The Agency research programme consists of non-collaborative studies aimed at specific spectrum management objectives and in direct support of the Agency's regulatory responsibilities, including its International role.

The focus is on making greater use of existing spectrum by developing more efficient frequency assignment and frequency sharing criteria. Studies also cover electromagnetic compatibility issues and extending the usable spectrum.

The RRAC advises on individual studies and the balance of the overall programme.

The RRAC also advises on European research co-operation with an emphasis on identifying programmes that have high potential.

6. Spectrum Efficiency Scheme (when established)

The Spectrum Efficiency Scheme consists of collaborative studies aimed at specific spectrum management objectives where those objectives are shared with non-RA parties who are willing to support the work.

The programme aims to solve common problems faced by the Agency and the radio industry in the medium and long term. Examples of potential research topics include agile systems, automated frequency selection processes and adaptive/dynamic channel assignment systems.

The RRAC acts as an advisory committee for the research aspects of the scheme and also takes a view on the training aspects.

7. Research Evaluation

The RRAC advises on a justified and supported radio propagation research programme. This includes the evaluation of the programme, against an agreed aim and the appropriate level of funding.

The RRAC keeps under review the justification of national facilities used by different researchers for various purposes and the rationale for stable long-term joint funding arrangement for these facilities.

For all research studies the RRAC advises on suitable measures of performance.

27 October 2000

Annex 2 RRAC Members list

Mr Peter Kiddle OBE (Chairman)
Mr Chris Cheeseman
Mr Tim Cull
Prof Jim James
Dr David James
Prof Peter Ramsdale
Prof Ray Steele
Dr Gary Tonge
Dr Walter Tuttlebee
Prof Peter Watson

RA Members:
Mr Barry Maxwell
Mr Mike Goddard

Secretariat:
Mr Vaughan Asque
Mr Martin Skingley (Meeting Secretary)
Mr Chris Carey

Annex 3a

TECHNICAL WORKING PARTY ON
MOBILE AND TERRESTRIAL PROPAGATION

REPORT TO RRAC, NOVEMBER 2000

1. Introduction

The Technical Working Party on Mobile and Terrestrial Propagation held its first meeting in October 1996, following a merger of the TWPs on Mobile Radio Propagation and on Diffraction, Scatter and Other Terrain Effects.

The Working Party covers the fields of mobile and terrestrial propagation mechanisms, particularly diffraction and scattering. The Terms of Reference are available separately. The membership has 59 representatives from 32 organisations, with a good balance between industry, academia and government. Four meetings are held per year, with an average attendance of 26 per meeting over the past year. Each meeting has standing business of reports from members, liaison with other groups and discussion of progress on the TWP's current "hot topic" area. This is followed by one or two technical presentations by members or invited speakers. The TWP maintains a Web site.

2. Activities of the TWP

In recent years the TWP membership have undertaken several major collaborative tasks in support of members' broad interests in the effects of terrain and terrain cover on services ranging from VHF to millimetre wave bands.

- production and maintenance of a database of diffraction path measurements for the use of members of the TWP in model development and comparison. A CD-ROM including some 50,000 records with the corresponding path profiles is available to TWP members.
- proposals for a common specification of three-dimensional "street-level" building databases for use in propagation models were developed by the TWP. Several TWP members are already involved in procuring such databases and in developing suitable propagation models that use these. A document describing the "Format for 3-D Geographical Datasets" was issued on behalf of the TWP, and presented to the RA Management Board.
- a questionnaire on the availability and accuracy of propagation models within the terms of reference of the TWP was circulated and analysed.

3. New initiatives of the TWP

In anticipation of its new role as a task group of the RRAC, the TWP has initiated discussions to formulate proposals for improving propagation models and to specify the data requirements and accuracies required to drive these models. The two areas being considered are 3G mobile and broadband FWA. Proposals for new work will be available for consideration by the RRAC early in 2001.

K.H. Craig
Chairman, TWP on Mobile and Terrestrial Propagation
November 2000

Annex 3b

TECHNICAL WORKING PARTY ON PROPAGATION FACTORS GOVERNING TERRESTRIAL FIXED SERVICE OUTAGES AT AND ABOVE 13GHz

REPORT TO RRAC, NOVEMBER 2000

1. Introduction

The FS-TWP is the youngest of the existing TWP's. It was set up in September 1997 specifically to look at problems operators are experiencing with outages on fixed links at frequencies around 38 GHz.

The TWP enjoys a membership of about 50 of whom around 30 regularly attend meetings. Members represent the Agency, other government departments, industry, research organisations and academia. Some 5 meetings are held each year. The meetings are characterised by a set agenda to hear and comment upon reports from members involved in the specific lines of inquiry, to determine further approaches or to identify needed resource. Following this are a number of presentations given by members as research progress warrant.

Terms of Reference for the TWP are available separately.

2. Activities of the TWP

Since this TWP had its origins in addressing a specific problem, its activities have been focussed on a limited number of matters which include precipitation, its statistics, attenuation and year to year variability. Some clear air issues and equipment issues. Additionally modelling as applied to Agency planning tools and represented in ITU-R standards have also been examined.

As this work was progressed a number of experimental projects were initiated by the TWP, largely funded by the Agency but also with a great deal of help in kind from the operators involved. This has seen some 18 months of measurements on real links, largely in the Southern part of the country, the construction of a novel transportable rain radar which will be deployed at St Andrews University this winter in another measurement campaign to examine the role of sleet in excess attenuation.

Theoretical work has been done at RAL and the Universities of Bath and Essex relating to rain statistics and sleet modelling which lead us to believe that international standards need some changes. It is also possible that Agency planning tools could be improved to result in greater spectrum utilisation. In a related issue, the work has highlighted a lack of propagation data covering all climatic areas in the UK. An interim report has been produced on the results of the first two years.

3. Future work

The TWP will continue to reinforce the roles of the campaigns already initiated particularly as their success is dependent on operator commitment and will examine the results as they are obtained. It is particularly interested in the application of rain statistics in UK planning, the improvement of standards and the new possibility of including some allowances for sleet in appropriate areas of the country. It has also expanded its terms of reference to enable it to contribute its collective expertise in the effects of precipitation on point to area systems such as Broadband Fixed Wireless Access. It is in a dialogue with the Mobile TWP to produce proposals for the consideration of the RRAC early in 2001.

D.Eden
Chairman, FS-TWP

Annex 3c

TECHNICAL WORKING PARTY ON HF PROPAGATION AND IONOSPHERIC EFFECTS

REPORT TO RRAC, NOVEMBER 2000

The Task Group meets twice yearly, usually at the RA in November and elsewhere in June, giving us the opportunity to visit various establishments and to view their facilities. The TG's activities are broadly concerned with HF radio propagation and ionospheric effects as they relate to radio systems. New terms of reference, which reflect the activities of the group, are being considered and are reproduced below:

1. To provide a forum for the reporting, discussion and dissemination of research results and activities on ionospheric propagation, related communication system aspects, and the noise environment.

2. To initiate and promote collaborative studies, including international study programmes, of aspects of ionospheric propagation and related topics.

3. To identify topic areas where further study is needed.

4. In considering the above topics to note current and developing priorities in the use of ionospheric systems. For example, the use of adaptive and frequency agile MF/HF communications, the introduction of digital modulation methods, the demand for higher data rates, the impact of PLT and DSL technologies, etc, trans-ionospheric effects.

Recently (1998), the TWP produced a report on *Current UK Research into HF Systems, HF Propagation, and the Ionosphere* which was given wide international circulation. It is felt important that the information contained therein is kept up to date and it is the intention of the TG to place the report on the WWW in a form in which the contributions from the various organisations and individuals can be readily updated. In addition, visitors to the web site will be able to extract information on particular topics of interest.

The activities of previous relevant COST initiatives have been closely considered by the TWP, reports being received at each meeting. The TG is actively supporting the UK contributions to the new COST-271 programme and it is likely that this will provide a major focus for our activities in the next few years. Scientists and engineers at various establishments within the UK, including several universities, commercial organisations, RAL and DERA have indicated their intent in participating in the COST programme, many of whom are also members of the TG.

E.M. Warrington
20 November 2000