Spectrum Issues for Next Generation Cellular[1]

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Summary
The current discussion towards spectrum assignment for extension bands to IMT 2000 is discussed in the context of the real needs of future multimedia based mobile radio services. Two unconventional methods are described to cover these needs: The first is co-farming of spectrum, where two operators agree to share a given frequency band alternating for different radio services under predefined conditions. The second is co-operation, where two organisations agree to make available part of their licensed spectrum to be combined in a way that a new radio service can be operated there by both of them together. Both methods contribute substantially to free spectrum for economically senseful usage and to reduce the scarcity of spectrum in general.

1. Introduction

ITU-R WP8F currently is discussing possible implementation and usage of the spectrum assigned by WARC-92 and identified by WRC-2000 for IMT-2000 family members to develop recommendations for the national regulation authorities of the different regions and countries. The main goal is to reach a maximum of international harmonization to prepare for global roaming.
The frequency bands under discussion internationally are not available for IMT2000 throughout all the regions. A consequence of this will be the demand for multiband and multimode terminals. The following chapters 2. and 3. are mainly reflecting the contents of [1][2].

2. Spectrum identified today for IMT-2000 systems

Figure 1 shows a comprehensive overview on the frequency bands identified by WARC-92 and by WRC-2000 for IMT 2000 systems. ITU-R WP8F - Spectrums Group currently is discussing the usage of these bands. The bands shown are not available in all the member regions internationally:

The IMT 2000 extension band 2500 to 2690 MHz – devoted for terrestrial radio services in the range from 2520 to 2670 MHz – is not available in some countries of Asia and in North America. This band will become availabe in other countries between the years 2005 and 2010, e.g., in Germany the band will be available from January 2008 on.

Frequency bands in use today for first and second generation mobile radio services, e.g., 451 to 466 MHz (C-Net in Germany), 806 to 960 MHz dependent on region and country (GSM900) and 1710 to 1885 MHz (GSM1800) will be available for IMT 2000 after the respective licenses will have expired or after the regulation conditions will have been changed accordingly. New assignments of these bands will be possible in Germany for 440 to 470 MHz in the year 2001/2002 and for the GSM bands from the year 2015 on.

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[1] Presented on Mobile Multimedia Conference, November 30, 2000, Berlin (IST project Drive presentation)
Presented on Wireless Strategic Initiative (WSI) Workshop, Brussels, Belgium, Dec. 12, 2000
[2] Werner Mohr: Alternative Vorschläge zur Spektrumsnutzung für IMT-2000 / UMTS, Spektrumsworkshop der ITU-R, 19.-20. October 2000, Genf

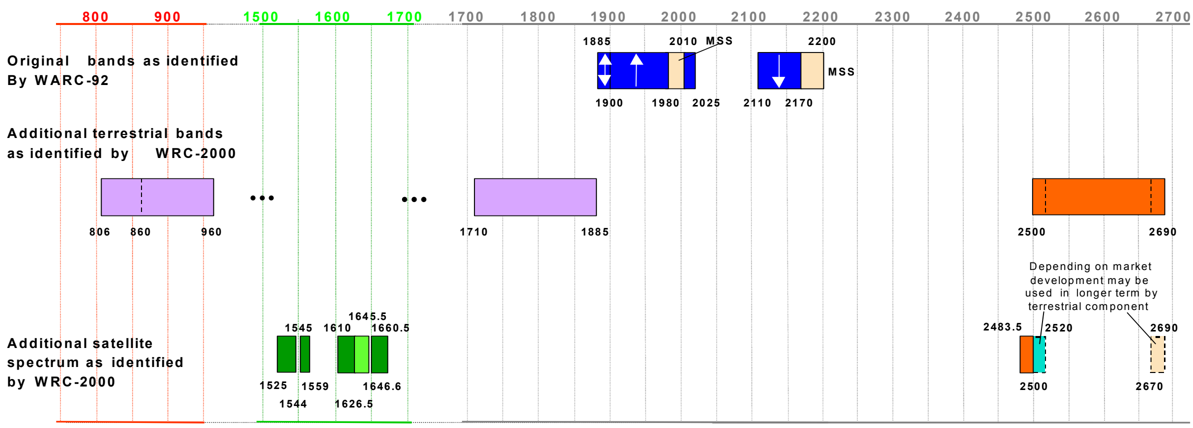

Figure 1: Overview on the frequency bands identified by WARC-92 (Source: ITU)

3. Asymmetric traffic characteristics of uplink and downlink usage

The higher the transmit rate of a service the higher is the expected asymmetry of usage of the uplink and downlink channels, making the downlink a bottleneck in IMT 2000 systems. The UMTS Forum has published a projection of the future usage of IMT 2000 systems and has identified the spectrum needed for the specific services, see Figure 2. A substantial asymmetry of the expected average traffic has been predicted there especially for Medium and High Multimedia traffic. The grade of asymmetry dependent on the services used might change from cell to cell over time and has to be taken into account when considering spectrum allocation for the extension of the currently available bands of IMT 2000. It would be optimum to be able to adapt the asymmetry of the spectrum load to the occupancy of the spectrum dynamically, dependent on the current load situation in a cell and on the development of the usage of services in a mobile radio system.

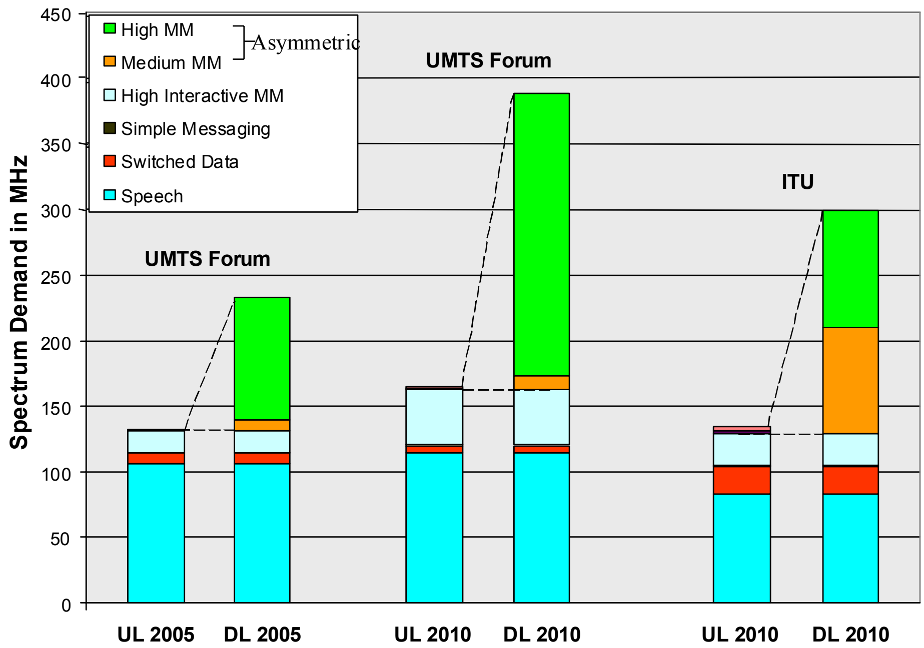

Figure 2: Projection of the future usage of IMT 2000 systems (Source: UMTS-Forum, Report No.6 and ITU-R Report M.[IMT.SPEC])

Two different approaches are under discussion to enable IMT 2000 systems to support a higher percentage of asymmetrical traffic that have been made from different angles of view:

3.1 Proposal by Advocates for More TDD Spectrum

The phases shown in Figure 3 are resulting from a proposal made by Siemens and can be described as follows:

- Phase 1: The IMT-2000 Core-Band is used for IMT-2000/UMTS according to the current licensing practice with
  - 2 x 60 MHz für FDD and
  - 20 + 15 MHz für TDD (in Germany the whole 25 MHz has been licensed for TDD).
- Phase 2: The extension band 2520 - 2670 MHz is proposed to be assigned to cover the needs of TDD-systems to serve asymmetrical data traffic. This band will be available in Europe between the years 2005 and 2010, in Germany the band is available from January 2008 on. In some Asian countries and in North America this band is not available.
- Phase 3: The GSM-1800 band is proposed to be re-allocated to be used for FDD-systems, this will be possible in Germany from about 2015 on.
- Phase 4: In this phase it is assumed that software radios and adaptive systems will be available to allow flexible use the spectrum in the subbands for both, FDD- and TDD-systems according to the market needs.

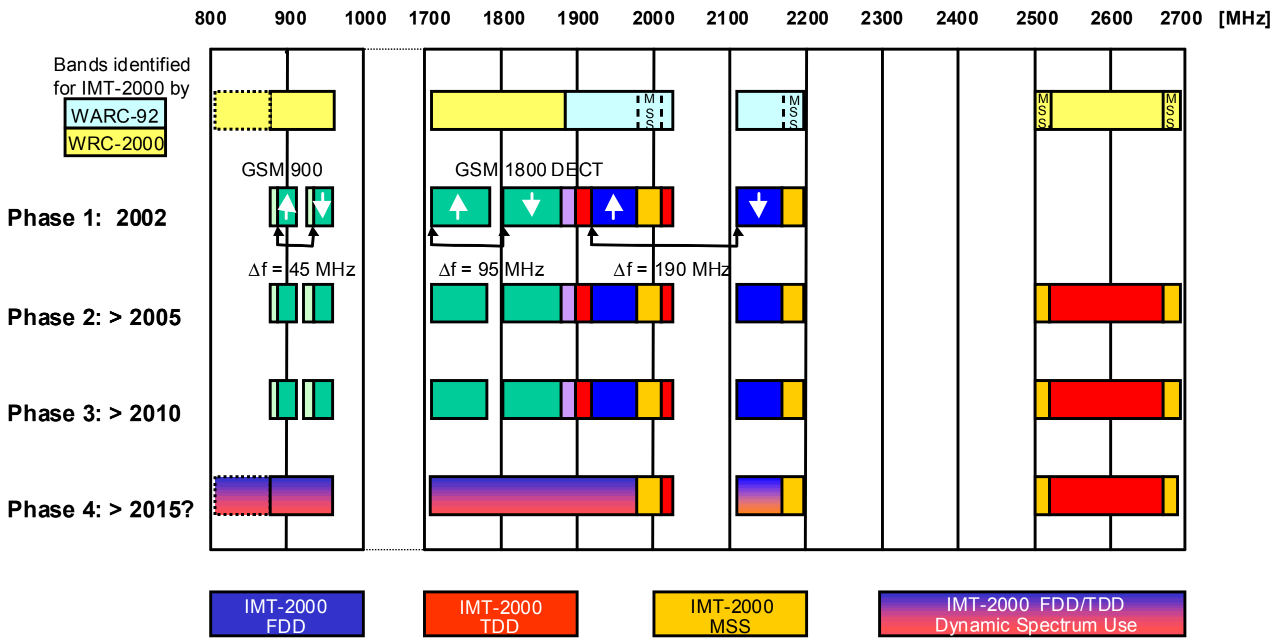

Figure 3: Assignment in favor of more TDD spectrum (Source: Siemens)

By this approach a decoupling of the separated subbands of the spectrum will be possible. Since there will be no time related dependencies between the subbands and their use for FDD or TDD, no problems related to the availability of spectrum for the one or the other mode of transmission will arise then.

In addition, the demand to support an asymmetrical traffic load needs can be responded in a flexible way.

3.2. Proposal to introduce an asymmetric operation of the FDD Mode

Figure 4 describes the basic ideas of how to introduce extension bands mainly to serve the UTRA-FDD mode of operation.

- Phase 1: This phase is identical to Phase 1 in Figure 3 and does reflect the current licensing plans and agreements.

- Phase 2: Here, the extension band does contain more downlink channels in addition to be able to support the needs of asymmetric traffic. By this a maximum degree of the mean asymmetricity of 1:3,5 can be realized by fixed channel allocation, that cannot be changed dynamically if needed. A consequence is that the air-interface must be able to handle a variable duplex spacing, since uplink and downlink channels will be grouped in a region or country according to the local decisions made by the regulation authority.
- Phase 3: The GSM-1800 band is now allocated to be used as an FDD uplink. Thereby, the asymmetry gained in Phase 2 will be turned the other way around: In case the duplex spacing between the GSM-1800 uplink and downlink of today is completely assigned as an FDD uplink, in fact there will result an allocation with more spectrum assigned to the uplink then for the downlink. In addition, the current band for the GSM-1800 downlink will have to be switched to become an uplink band. It is expected that this will result in co-ordination problems at country boarders throughout Europe and in other continents and will make difficult to avoid adjacent band interference there.

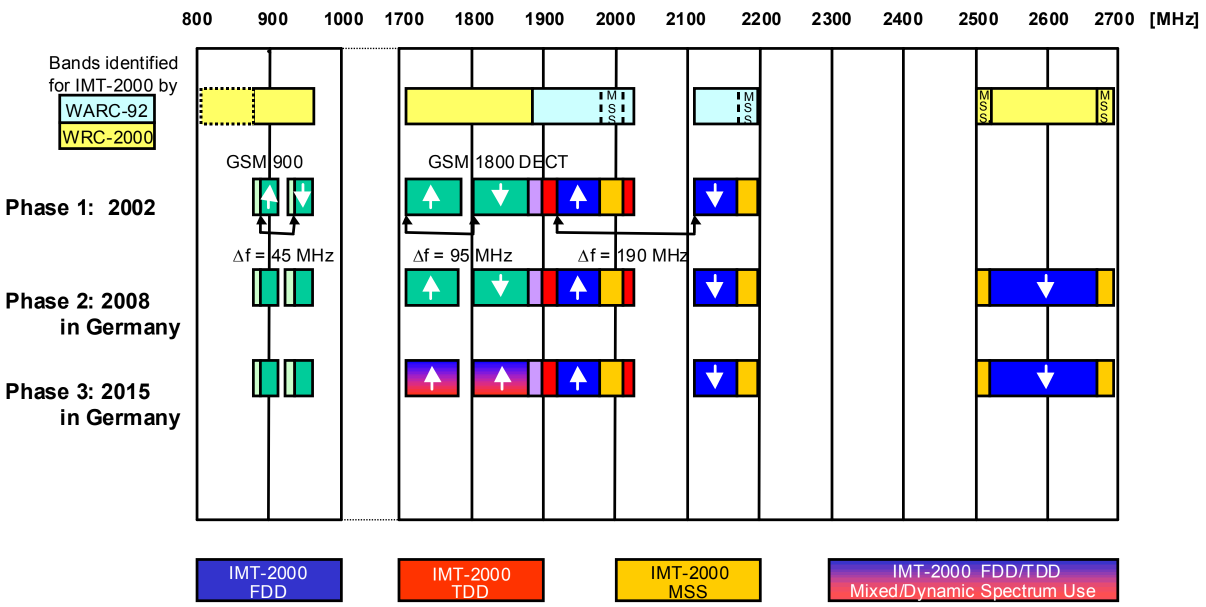

Figure 4: Assignment in favor of more spectrum to asymmetrical FDD operation (Source: ITU)

In the following two unconventional methods are described to cover the needs for more spectrum to especially serve asymmetrical traffic streams: The first is co-farming of spectrum, where two operators agree to share a given frequency band alternating for different radio services under predefined conditions. The second is co-operation, where two organisations agree to make available part of their licensed spectrum to be combined in a way that a new radio service can be operated there by both of them together. Both methods contribute substantially to free spectrum for economically senseful usage and to reduce the scarcity of spectrum in general.

4. Co-Farming of Spectrum by the Defense Community and Public Cellular Operators

We propose to perform an in depth investigation of the practicability of the time-shared use „co-farming“ of spectrum assigned by WRC, Nato, EC, and national governments to the defense community by both, wireless/cellular operators and the defense community. The approach in part also applies to the relation between broadcasters and cellular operators.

4.1 State of the Art of Spectrum Allocation

From the Detailed Spectrum Investigation (DSI) Process Phase III (862-3400 MHz) of ERO of July 1998, (available from http://www.ero.dk/eroweb/DSIinfo.html)

- it is clear that in the fixed network the relative load by data has exceeded that of voice in 1998 (see page 21), a development that experts expect to happen a number of years later also to wireless and mobile radio networks
- „Trends and Developments for the Military Services“ within the DSI range can be found (NATO unclassified), see page 106-114.

The Green Paper on Radio Spectrum Policy (distributed by EC, Brussels, 09.12.98 COM(1998) final) distinguishes

- five radio-based sectors and activities (see Table 1 on page 5)
  - Telecommunications
  - Broadcasting
  - Transport
  - Government (comprising Defense, Emergency, Law enforcement, Space science, Applications under international commitments)
  - Research&Development
- three parts of the spectrum, i.e.,
  1. 9 kHz to 1 GHz
  2. 1 GHz to 3 GHz
  3. 3 GHz to 30 GHz

Table 2 shows an example from the UK, where „Defense“ owns in

- part 1. 29%,
- part 2. 31%,
- part 3 38%

of the frequency spectrum. The situation is similar in other member states of the EU. The future growth of wireless and mobile applications will lead to a dramatic shortage in radio spectrum for public use. The government as the owner of the spectrum has assigned more than 30% of the available spectrum to the defense community.

4.2 The Current Situation in Spectrum Use by Public and Non-Public Users

Periodic negotiations are performed on the national and european levels between regulatory authorities and the respective defense community representatives aiming to refarm sectors of the spectrum used by the defense community for public telecommunications use. The arguments have been repeatedly exchanged and the process will not end with significant changes of the current allocations. This is partly owing to convincing arguments of the defense representatives and partly to a lack of motivation of the defense community to release a given band and carry the cost to reallocate the respective radio equipment to another band.
A close look on the usage of the defense bands reveals that substantial pieces are only rarely used and some parts are not used, being reserved for a case of need, e.g., the tactical bands.

4.3 The Proposed Improvements and Related Research

Public telecommunication operators in most cases receive their licensed spectrum against fees for a limited time duration, e.g., from an auction controlled by a national regulation authority. UMTS spectrum, for example, in some countries in Europe has been licensed from auctions for a fee of up to 3 to 4 billion US $ per 5 MHz block (duplex) for a duration of 20 years.

It is proposed to study the co-farming of suitable frequency bands of the defense community by time-shared use of public and defense users. In a time-shared use most of the time the public operator will have free access to the respective bands, but under well-defined conditions the owner of the band (members of the defense community) may withdraw the band for its own usages for some time interval. This idea is a small modification of the current situation: operators of public cellular radio networks, e.g. in Germany, have been contracted to close down or reduce their services and give spectrum to the defense community on request, e.g., in times of crisis.

Time-shared use can be seen as equivalent to co-farming a band or to frequency borrowing and could happen under, e.g., the following set of agreements:

1. Co-farming of a given band with a public operator is under the control of the owner (that might be the government or its representing department of the defense community), i.e. the owner may claim a temporal partly or exclusive use of the respective band under certain previously agreed circumstances (typically a rare event) and the band may then be withdrawn from the public operator.
2. A public operator using a co-farmed band would have to pay a license fee to the owner or its representative, the amount of which depends on the true market value, i.e., the defense community will receive a compensation for making a band to a limited extent available for public use.
3. The public operator must own a license for a wireless or mobile radio system based on a public band and may enlarge his service capacity by using a co-farmed band; the offered service should be engineered by the operator in a way to be able to guarantee a reduced service to its customers when the co-farmed band during some time intervals would be not available for the public service.
4. The owner of the co-farmed band must use the revenue raised for the modernization of its own radio equipment.

These items are examples only and should be complemented to cover all eventualities fore-

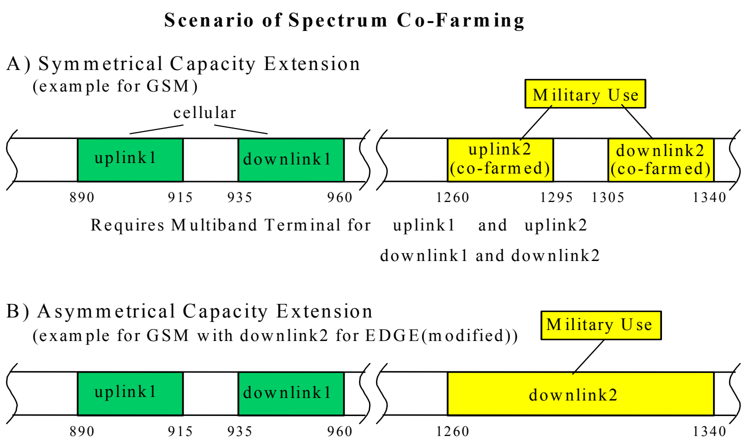

Figure 5: Two alternate ways to co-farm a defense community owned band by a public cellular operator a) symmetrical, b) asymmetrical

seen. The proposal is to leave the defense bands under the control of the defense community but make some of the bands available to the public under a fair sharing agreement – against payments. Figure 5 gives an example how to extend the traffic capacity of a cellular operator of, e.g., a GSM900 system by co-farming the spectrum owned by a number of military organisations. Two cases have been differentiated: symmetrical and asymmetrical extension of the cellular operator's capacity by co-farming a symmetrical or asymmetrical band, respectively. The main ideas presented are applicable also to the co-operation of radio broadcasters and public cellular operators.

4.4 Preparatory and Validation Steps Before Introducing Spectrum Co-Farming

The proposed co-operation between public and defense operators need a validation of the practicability before introducing it into practice. This validation of praticability and the development of measures to secure the guarantee of full control of the defense community over their allocated bands, should be performed as part of a 5th framework project. Besides others, the candidate bands have to be identified and the praticability of the proposed co-farming and service quality reduction when the borrowed band is withdrawn have to be investigated. Further, the relation of licensed and borrowed band of a public operator under the conditions of its service mix being offered have to be developed. It appears advantegeous to co-operate with defense community representatives and manufacturers of military radio equipment to better understand the problems and find adequate solutions. Besides that, commercial and competitive aspects have to be studied.

4.4.1 Example of Withdrawing of a Co-Farmed Band

Although it can easily be imagined that a defense band, being borrowed to operate the downlink of a public radio service, can be easily freed by closing the respective frequencies used by the base stations under central control, it can also be imagined that mobile terminals can be operated in borrowed bands and can be switched out of the band, e.g., by means of a pilot tone issued via the broadcast control channel under central control from the defense community. (The protocols for this function have to be developed). Since military organisations are used to live with jamming their spectrum, it could even be acceptable if some of the mobile terminals would ignore the busy tone and would continue to temporarily issue attachment signals.

4.5 Advantages of spectrum co-farming for the defense community

The defense community is assumed as part of this proposal to raise money from borrowing spectrum to public operators during co-farming.
If the defense community is contracted to modernize its radio equipment operated (rarely) in the borrowed band, it might be advantageous when modernizing the equipment to switch from a military air interface standard to an ETSI/ITU-R standard used in the public system operated in the co-farmed band. During an intermediate stage, where current and modernized equipment is used in parallel, the public band might be used by the respective defense organisation.
As a result, the defense community would in the medium to long term, after a complete phase of modernization, use the same air-interface standard in the borrowed band as is used in the corresponding public band (of cause the security measures will be kept at a much higher standard). This would contribute to dramatically reduce the cost of military radio equipment, since it would follow the standards of the mass market and therefore would accelerate the modernization of the military radio equipment. Although this might not be the interest of the respective manufacturers, it appears to be the interest of the tax payers.

More carefully looked into the resulting scenario it would become clear that a distinction between borrowed band and public band would disappear, because it would be much better for the military communications traffic, when generated, to virtually disappear in the high volume traffic of the public users instead of applying costly and spectrum consuming spreading and security measures to avoid detectability and observation of defense related traffic. The public traffic in Erlang is estimated to be about thousand times higher than the defense related traffic even in a military hot spot. In fact, even no traffic flow analysis of the military spectrum use would be possible and eavesdropping would become practically impossible without any cost.

The scenario described is in line with the philosophy followed anyway by the defense community in these days. Off-the-shelf (standard) equipment (e.g., Ethernet and PCs) is used wherever possible. And this philosophy has not only proved in many cases to be superior to the use of dedicated military equipment but also has proved to be in many cases the only possible way to keep pace with the technical progress in the respective domains.

5. Co-operation to Co-farm a Broadcaster's Licensed Spectrum with a Cellular Operator

Broadcasters have been assigned excessive spectrum for radio and television broadcasting, e.g. 368 MHz in Germany that they are currently unable to use efficiently: In most places of the country substantial parts are not being used.
The number of subscribers using terrestrial television services, e.g., in Germany is about 8%, the others are accessing these services via cable or satellite. The pure operations costs of terrestrial broadcasting in Germany is about 500 Mio. DM per year. This amount of money would be sufficient to grant all the users linked to the terrestrial television broadcast service a satellite antenna plus decoder to switch to satellite reception and cut-off from terrestrial television broadcast services. Even if part of the costs would remain then to operate the terrestrial radio broadcast service, the spectrum assigned to television would be free for new usage.
The economic value of the spectrum usage by broadcasters is very questionable. The spectrum, e.g. in Germany, is licensed to broadcasters for free, based on an Article of the „Grundgesetz" guaranteeing access to broadcast information for every citizen in Germany to be able to „make up his political mind". With 8% of citizens only that use this terrestrial service offer, and considering that alternate service provisions are easily available based on satellites and cabled systems, the sensefulness of the allocation of such huge amount of spectrum in the best part of spectrum is very questionable.
Mobile cellular radio operators alltogether currently have been licensed about 365 MHz of spectrum for which they had to pay substantial fees to the national regulation authority. One argument was that spectrum is very scarce and a fair market value of spectrum at best can be found by means of an auction. Mobile radio operators raise a big economic values out of the spectrum they are using.
Since more spectrum is needed for mobile radio operation, frequency refarming of spectrum allocated to broadcasters should severely be discussed. It should be clear from the initial that the goal is not to take-over the whole spectrum currently licensed to broadcasters by mobile radio operators, but to get access to a substantial portion of it to be able to cost-efficiently provide radio coverage in rural areas of the country.

There currently exist plans of governments in Europe to re-assign the television spectrum in steps to be used for digital broadcast transmission based on the DVB-T standard. Since the terrestrial customers affected by this decision would then have to decide whether to buy a new digital (DVB-T) terminal equipment or to buy a satellite receiver to keep their existent terminal operational, there is a high risk of this process that terrestrial broadcasters would experience a decline of their market share from 8% to, say 0,8%.

5.1 Lessons learned from UK

In UK a model has been developed and exercised that allows industrial companies to operate a commercial digital pay-per-usage service on about 20% of the former television bands using DVB-T on the downlink and various networks to provide an uplink channel back from the customers to order services from the commercial companies. DVB-T terminals that can receive the whole television radio band have been given for free to the customers by the commercial service providers.
The UK-broadcasters by means of this trick have solved the problem to survive the switching from analog to digital transmission and not to loose their terrestrial customers.
As a result there now exists a competition between public cellular operators and operators of DVB-T-with-backchannel services established by the UK government that mainly offer multimedia contents that otherwise would have been carried by UMTS operators in UK.
The question is whether or not this model can be ported to other European countries, e.g. to Germany and thereby establish competition between government-supported operators that use television bands for countrywide bidirektional services and UMTS operators that have recently paid quite much to get an UMTS license. My guess is that this will be difficult to repeat elsewhere in Europe.

5.2 Alternatives to Co-farm Television Spectrum by Cellular and Broadcast Operators

The current situation of spectrum usage for television services between 470 and 838 MHz as shown in Figure 6 will be reconsidered in 2003 by WRC for the years beyond 2010. It can be seen that between 838 and 862 MHz a military band exists adjacent to this band. The channel width is 8 MHz for the television channels. The channels from 814 to 838 MHz are reserved for transmission using the new DVB-T standard for digital television broadcasting.

The scenarios 1 to 3 shown in Figure 6 have been developed by the COMCAR[3] and DRIVE[4] projects that perform research towards the integration of television services offered via the broadcasting bands and of services offered from public cellular operators. Since it would be optimum for a radio terminal to make use of spectrum bands that are closely neighboured, in Scenario 1 an example is shown where the cellular radio band (shown in dark/blue) is operated in channels of the military band 814 - 862 MHz.
A Scenario 2 shows alternate spectrum usages to operate the public cellular radio system somewhere in channels of the spectrum currently allocated for television broadcasting. It should be taken in mind that the usage of the television band is different in the states of Germany, dependent on the locations and that the positon fo free television channels for cellular radio use therefore need to be location dependent. The different radio services namely analog TV, digital TV and cellular will have to coexist in a way that no unacceptable interference would result from introducing, e.g., UMTS transmission via a 8 MHz channel of the television band. This appears to be possible since UMTS has a channel width of 3.8 MHz that is typically embedded into a 5 MHz channel to avoid neighbour channel interference.
The Scenario 3 is going even beyond what is proposed by Scenario 2: a number of TV-channels there has been permanently allocated to serve cellular radio. In addition, the ideas presented in the other two scenarios are kept as part of Scenario 3, namely co-farming of military spectrum and of television spectrum by cellular radio.

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[3] Communication and Mobility by Cellular Advanced Radio, funded by the Federal Minister for Education and Research in Germany
[4] Dynamic Radio for IP-Services in Vehicular Environment, funded by CEC in the Information Society Technology Programme

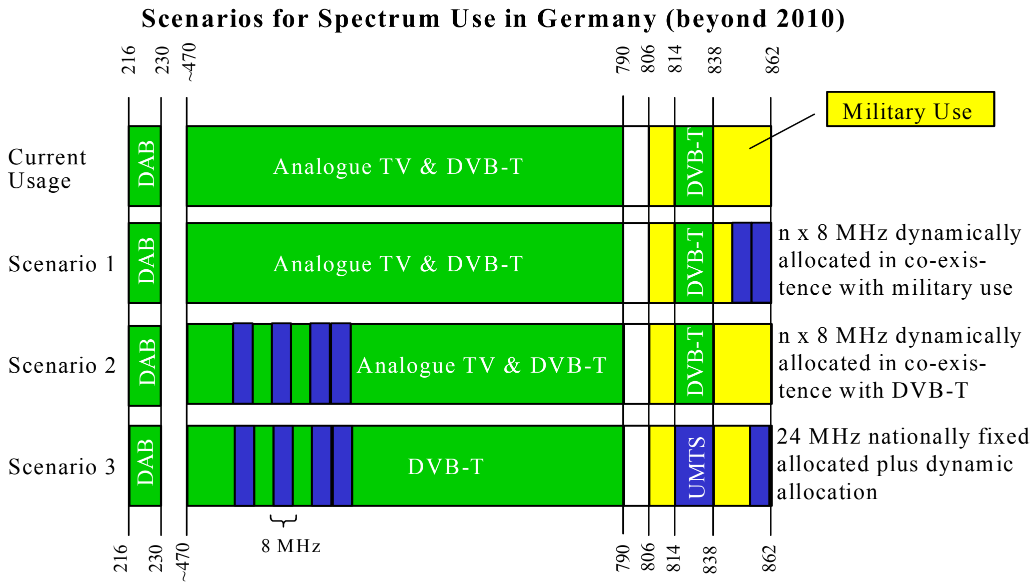

Figure 6: Proposed usages of broadcaster's and military spectrum by cellular (UMTS) radio as studied by the projects COMCAR and DRIVE

The hope of the activities is to get experience with the combined operartion of different systems and to convince television operators, regulators and government resposibles that it is a good idea to join the forces of TV-broadcasters and cellular operators, say, by means of a common subsidiary company to operate the combined service. This would enable broadcasters to make more efficient use of their spectrum than nowadays.
The author had developed and communicated the ideas presented in this paper since summer 1998 and since then has experienced much interest und support from different parties involved, namely members of the defense community, the regulation authorities of different countries, manufacturers and operators of mobile radio systems and broadcasters.

Conclusions

It is proposed to provide legal conditions and technical measures to make more efficient spectrum use possible of frequency bands assigned to the defense and broadcasters communities. The co-farming use of the respective bands appear to be advantageous to all of the involved parties and spectrum would be used in a much more efficient way as is the case in these days. Scarcety of spectrum could be overcome by this. A study initiative is proposed to investigate in detail how the co-farming could be performed without violating the interests of the involved partners.