

RSPG

DRAFT RSPG OPINION ON EU SPECTRUM POLICY IMPLICATIONS OF THE DIGITAL DIVIDEND¹²

1. Introduction

This paper represents the Radio Spectrum Policy Group's (RSPG) response to the Request for an Opinion on the EU spectrum policy implications of the digital dividend.

This opinion represents a follow-up and a complement to two opinions previously adopted by the RSPG, respectively on:

- **“Spectrum implications of the switchover to digital broadcasting”**³ (23 November 2004), which highlighted, among other aspects, the importance of the prospect of a digital dividend.
- **“Spectrum for mobile multimedia services in the field of broadcasting”** (Mobile broadcasting), which addresses a particular case of potential use of the digital dividend, which may also rely on frequency bands different from within the scope of the digital dividend,

It is also a follow up of two recent Commission Communications: **“Accelerating the transition from analogue to digital broadcasting”**⁴, which sets out the Community policy objectives for the transition, and **Radio spectrum availability in the context of the digital switchover and the upcoming ITU Regional Radiocommunication Conference 2006 (RRC-06)**⁵.

This new RSPG opinion should be considered as a generic initiative to approach the issue of the digital dividend on a Community level, and not as an attempt to impose any particular solution on individual Member States for the sake of uniformity. It is intended to address the prospects of the digital dividend and to identify any need for coordination at EU level. In particular, the scope of this opinion encompasses virtually all potential uses of the digital dividend.

¹ Editorial note: parts taken from the draft opinion on multimedia services are highlighted in yellow.

² This draft opinion does not at this stage reflect the views of Member States, but only the status of work in progress.

³ Full text of the RSPG Opinions can be found at the following web address: http://rspg.groups.eu.int/documents/meeting_documents/index_en.htm

⁴ COM(2005) 204 (24 may 2005).

⁵ COM(2005) 461 (29 September 2005).

2. The digital dividend and its possible forms

In order to facilitate its task, an initial questionnaire was sent out by the RSPG to the Member States and administrations of countries adjacent to the EU. A summary of the responses received is provided in Annex 1

The responses received have pointed out different interpretations on the meaning of the digital dividend by various administrations. For the purpose of this opinion, consistent with the previous RPSG opinion on digital switchover, the digital dividend is understood as the spectrum made available over and above that required to accommodate the existing analogue television services in a digital form, in VHF⁶ (band III: 174-230 MHz) and UHF bands (bands IV and V: 470-862 MHz). It is expected to be fully available throughout Europe only after complete switchoff of analogue television (2012 EU objective, 2015 ITU legal deadline), although some countries have announced availability of this digital dividend in certain areas prior to that date.

Its possible forms include:

- Broadcasting
 - Higher number of programs
 - increased coverage
 - Local television
 - High definition television
 - Mobile or portable reception
 - Data broadcasting,
 - Enhanced TV
- Electronic communications
 - Mobile telephony/broadband
 - Broadband access to scarcely populated areas
 - Services Ancillary to broadcasting, which already coexists with broadcasting
 - Low power devices (licence exempt or not).
 - Private mobile radio
 - Military communications/
 - Public Protection and Disaster Relief (PPDR)

Some of these possible forms might have the capability of exhausting the digital dividend. However, the impact of advance coding methods, such as MPEG4, should be taken into account as a mitigation element, which could at least partially compensate for the demand of additional spectrum.

⁶ Band I: 47-68 MHz, has been mentioned as offering a potential scope for digital dividend. This band however, has not been considered in this Opinion.

It should be noted that different interpretations currently exist as to regulatory fit of multimedia. Some administrations regard it as mobile TV and an extension of broadcasting, while others consider it as an extension of cellular 3G services.

3. The regulatory framework established by the Geneva 2006 Agreement, its limitations and possible scenarios

As pointed out in the RSPG opinion on multimedia services, the use of the frequency bands 174-230 MHz and 470-862 MHz by digital broadcasting has been planned by the GE06 Agreement, which has de facto harmonised the technical parameters for digital broadcasting and introduced flexibility for future systems. This situation enables administrations to satisfy their evolving spectrum requirements in these bands in many different ways.

In particular, the GE-06 Agreement leaves significant flexibility in implementing the Plan:

- the concept of allotment planning provides a high degree of flexibility regarding the location of broadcasting transmitters within the corresponding service area and interference envelope of the entry in the Plan.
- The concept of spectrum mask offers flexibility for implementing broadcasting services with different characteristics or other applications, provided the interference and the protection requirement are kept within the envelope of the corresponding entry in the Plan. If the proposed use exceeds the limits of this envelope, it requires prior agreement from affected administrations.

Limitations exist however, which have already been pointed out in the RSPG opinion on multimedia services, and may constrain the use of the digital dividend:

- The use of these bands for digital services will continue to be constrained until protection of analogue transmissions has ceased, which is generally expected in 2012, but sooner in some countries in the EU. It should be noted however, that the date fixed by the Conference is 2015, and that this could constrain countries located at the periphery of the Union;
- Although the plan modification procedure provides a suitable framework for administrations to adjust their entries in the plan as future requirements arise, it should be recognised that the flexibility left to administrations for developing the plan has already leads to significant variations in the entries, hence in the ability of harmonising usage in the future.
- In many countries, the implementation of mobile multimedia services may require departing from the reference planning configuration adopted before RRC-06, hence entail delays and network costs.
- For reasons related to handset design and cost, a minimum frequency separation will be needed between the channels used for multimedia reception (“downlink”) and the frequency used for transmission by the mobile terminal (“uplink”). This is a constraint if

the 900 MHz band is to be used for the uplink and the 470-862 MHz is to be used for the downlink in the same handset.

- Although other services may be operated within the limits of the envelope of an entry in the Plan, hence receive indirect recognition and protection, it is not possible to notify to the ITU mobile uplink transmissions in this band. This situation may be perceived as a lack of full international regulatory recognition for such uplinks, and this may be alleviated by seeking an additional allocation to the mobile/fixed service in the entire UHF band at WRC-07/10, under conditions which ensure that the broadcasting service is not adversely impacted.
- Use of fixed/mobile uplinks would also require guardbands with television or sound broadcasting, hence make their coexistence and coordination difficult. This could be alleviated by harmonising a sub-band of the UHF band for fixed/mobile services, at the European level and preferably at the ITU level, without prejudice to administrations intending to continue to use the same sub-band for broadcasting services. Such harmonisation would also enable the design of terminals with improved antenna gain characteristics and the definition of a common channelling arrangement, hence reduce the cost of the fixed/mobile networks and facilitate their coexistence with broadcasting networks. However, given the commitment to digital switchover planning in most Member States, it could be difficult to identify a common sub-band and hence alternative approaches should also be considered.
- Harmonisation of part of the VHF band for mobile uplinks is less attractive, due to its small size. This does not prevent some types of communication networks to coexist successfully with broadcasting in this band, although not without inefficiencies. Therefore, no specific action seems necessary in that band at this stage. More studies may be required to assess the possibility of further sharing arrangements in the future.
- Technical constraints to the frequency planning may arise to ensure coexistence of broadcasting networks intended for fixed rooftop reception and broadcasting multimedia networks (including mobile or fixed networks) intended for indoor portable reception. Studies are urgently required to ensure that the appropriate measures are identified to overcome these constraints.
- [A requirement has been expressed for the use of parts of the digital dividend for Public protection and disaster relief (PPDR), taking into account the current difficulties to identify an appropriate solution for, and the benefits of, a harmonised sub-band at a EU level. This may respond to the need expressed by the European Council at its extraordinary meeting of 7 January 2005 (press release [5142/05]).]

These limitations and the possible regulatory/harmonization decisions that could be taken to overcome them may be summarized in the following Table.

Table 1 – Possible regulatory/harmonisation steps beyond GE-06 Agreement in UHF/VHF bands and associated goals/advantages

Regulatory/ Harmonisation steps	Intended Service	
	Broadcasting, fixed, mobile (downlinks only)	Fixed/Mobile (including uplinks)
ITU Regulatory framework and possible changes	GE-06 Agreement sufficient	GE-06 preferably complemented by an additional allocation to the fixed/mobile service across the entire UHF band at WRC-07/WRC-10 (perceived full recognition)
ITU harmonisation and possible changes	GE-06 Agreement provide sufficient de-facto harmonisation	GE-06 preferably complemented by identification of part of UHF band for specific applications/systems. (worldwide economies of scale)
Possible European harmonisation steps	<p>Non mandatory decision for administrations to make available one or two layers for high field strength downlink services in a sub-band of UHF band.</p> <p>(Europe-wide availability of service for interactive services with uplink in 900 MHz band, Europe-wide market, improved terminal performance/reduced network costs and improved compatibility with fixed reception broadcasting through reduced bandwidth)</p>	<p>Non mandatory decision for use by fixed/mobile services (including uplinks) in a sub-band of UHF band.</p> <p>(Europe-wide availability or service and roaming, Europe-wide market, economies of scale for terminals and networks, improved terminal performance/reduced network costs through reduced bandwidth and common frequency arrangement, reduction of digital divide)</p>

Assuming that the regulatory/harmonisation steps described in Table 1 were to be taken, the question then arises of how the GE-06 Plan and procedures could be used by administrations to transition to the new situation with minimum efficiency losses.

As part of the GE-06 Agreement, each country has been allocated a total of 7 to 8 full-coverage layers in the GE-06 digital Plan. This means the territory of each country had been divided in allotment/assignment areas, with each of them receiving 7 or 8 channels. To prevent interference, the channels used in one area are different from those used in neighbouring areas. RRC-06 has optimized the process of allocating channels to areas in a way which provides each country with the same number of full layers (the equitable access principle). This number was the maximum achievable at RRC-06, i.e. it entails a fair level of optimization, calculations and multi-lateral negotiations. Therefore leaving out a significant part of the UHF band for purposes other than broadcasting would leave each of the existing layers incomplete.

In the absence of significant re-planning activities, it would in general be feasible to make available one or two layers per country for high field strength downlink services. However, the resulting channels would spread across a significant portion of the UHF band and would not be the same from country to country. This would not alleviate the potential coexistence difficulties mentioned above between fixed reception networks and portable indoor reception networks nor enable to take full benefits of optimized terminal costs and performance. Further studies are therefore required to address this issue.

However, identifying a sub-band dedicated for mobile applications (including or not uplinks) would create holes in most of the layers obtained at RRC-06. It would not be possible to make up for these losses in the remaining available spectrum without significant re-planning activities.

Another issue to be considered is that the use of the channels in the sub-band dedicated to mobile uplinks would be constrained by the use of broadcasting in other countries, should these countries prefer not to use it for mobile.

It should be noted that in several European countries, licences have been given for the provision of digital terrestrial television in the UHF bands for the next 15 to 20 years. Any decision on the use of the digital dividend will therefore need to take into account the spectrum requirements associated to these licences.

4. The Opinion of the RSPG

The purpose of this Opinion is to address the EU spectrum policy implications of the digital dividend.

4.1 Before switchover, which is generally expected to occur in the period 2008-2012, many Member States intend to give priority to broadcasting services, taking into account the constraints arising from the transition from analogue terrestrial television. After switchover, some Member States indicate a preference for using the digital dividend for enhancing the broadcasting service, while other express a preference for keeping the

- choice open or have not formulated an approach as to the foreseen use of the digital dividend.
- 4.2 Any approach for the implementation of the digital dividend should take into account the Opinion adopted by the RSPG on WAPECS.
 - 4.3 Many promising new services fostering growth and innovation are seeking urgent and easy access to the UHF and VHF spectrum, among other bands. In this context, European action to enable the development of such services in these bands must be taken in a way that optimize the use of spectrum as a whole, promotes and does not distort competition, encourages innovation, maximises benefits across the European Union, and does not conflict with national and European content legislation aiming at promoting cultural diversity and media pluralism.
 - 4.4 The economic and societal merits of the various alternatives proposed for the use of the digital dividend should be taken into account.
 - 4.5 This opinion complements the opinions it has previously adopted on “the spectrum implications of switchover to digital broadcasting” and on “the development of multimedia services”.
 - 4.6 Existing licences to provide analogue and digital broadcasting services along with legal decisions taken at national level concerning the licensing regime in digital terrestrial television or sound broadcasting may affect the ability to find spectrum to deploy other new services. In particular, it may be difficult in some countries to gather substantial and coherent amount of spectrum for the digital dividend for use by services other than broadcasting before 2012.
 - 4.7 The use of the frequency bands 174-230 MHz and 470-862 MHz by digital broadcasting has been planned by the GE06 Agreement, which has de facto harmonised the technical parameters for digital broadcasting and created a global market for digital broadcasting equipment.
 - 4.8 Technical constraints to frequency planning may arise between broadcasting networks (RPC-1, 2 and 3), multimedia networks and fixed/mobile networks in the same band and considers that studies should urgently be undertaken to identify and address these constraints so as to facilitate the effective use of spectrum. Noting the immediacy of switchover in some countries and the consequential narrow window of opportunity for decisions on the use of the digital dividend in Europe, studies are urgently required within CEPT to assess the technical feasibility of the various options to be considered.
 - 4.9 In the band 174 – 230 MHz, various alternative services may already be deployed under the GE06 Agreement, using various technologies. Hence no action appears to be necessary at EU level at this stage. More studies may be required to assess the possibility of further sharing arrangements in the future.

- 4.10 In the band 470 – 862 MHz, there would be EU-wide benefits to the use of the digital dividend by broadcasting services. The current international regulatory framework, as settled by the Radio Regulations and the GE-06 Agreement, provides an appropriate framework for this development. Within this framework:
 - 4.10.1 In the absence of significant re-planning activities, it would in general be feasible to make available one or two layers per country for high field strength downlink services. However, the resulting channels would spread across a significant portion of the UHF band and would not be the same from country to country.
 - 4.10.2 The identification, at European level, of a common (but not dedicated) sub-band of the UHF band for high field strength downlink services would permit improved terminal performance/reduced network costs and improved compatibility with fixed reception broadcasting, and facilitate interactive services using the 900 MHz band for the return channel. However, this common sub-band should not be too narrow since it may lead to significant replanning activities in order to make available one or two layers per country for such services.
 - 4.10.3 Studies should therefore be urgently undertaken by CEPT in order to consider these two approaches and identify an optimum way forward for high field strength downlink services, enabling the availability of one or two layers per country while avoiding the need for significant replanning.
- 4.11 There may be EU-wide benefits to the use of the digital dividend by fixed/mobile applications (including uplinks) in a harmonised sub-band of the UHF band and that this would be facilitated by:
 - 4.11.1 Seeking an additional allocation to the fixed/mobile service in the entire UHF band at WRC-07 or WRC-10, under conditions which ensure that the broadcasting service is not adversely impacted.
 - 4.11.2 In parallel, initiate within CEPT the studies required to select this sub-band with the objective of developing a non-mandatory decision at European level to facilitate the use of fixed/mobile applications (including uplinks), under certain harmonized conditions to be defined and adopted in the 2007-2010 timeframe.
 - 4.11.3 Seeking endorsement of this non-mandatory harmonisation at ITU level at WRC-10, through identification of part of UHF band for specific applications/systems.
 - 4.11.4 However, identifying a sub-band dedicated for mobile applications (including or not uplinks) would create holes in most of the layers obtained at RRC-06. Making up for these losses in the remaining available spectrum would require significant re-planning activities.
- 4.12 There would be considerable EU-wide benefits to the use of more advanced television coding systems (such as MPEG-4) and that Members States should consider their introduction at the earliest possible date.

- 4.13 In the event of an ITU/ European identification of a sub-band of the UHF band for fixed/mobile applications (including uplinks), the need for a conference of the Chester-97 or RRC-06 type in the timeframe 2010-2012 in order to plan the use of the remaining part of the UHF band allocated to broadcasting only, should be carefully assessed, together with alternative, potentially less efficient but less costly approaches relying on bilateral/multi-lateral coordination.

ANNEX 1

ANALYSIS OF THE RESPONSES RECEIVED TO THE RSPG SUB-GROUP QUESTIONNAIRE ON DIGITAL DIVIDEND

Future use of the UHF and VHF Bands

1. Have you held or are you planning to hold national consultations on the issue of the digital dividend? If not already held, when? Please give details on the responses received.

Most countries were waiting the outcome of the RRC-06 before addressing the issue of the digital dividend. Several countries have started to investigate the issue by setting up working groups or specific structures, but only one administration (Sweden) has reached the point of public consultation. No administration has come to a final decision on this issue at this stage.

2. Have you preferences as to the foreseen use of the digital dividend in your country?
 - a. Before the expected EU wide analogue switchoff (2012)
 - b. After the expected EU wide analogue switchoff (2012)

The responses provided have pointed out different understandings of the meaning of the digital dividend by various administrations: many consider it to be the spectrum left after digital broadcasting requirements have been satisfied, whereas others understand that the digital dividend is the spectrum made available by analogue broadcasting switchoff. Although it may appear as somewhat artificial, this matter has to be clarified fully within the opinion.

Before switchover, which is generally expected to occur in the period 2008-2012, many Member States intend to give priority to broadcasting services, taking into account the constraints arising from the transition from analogue terrestrial television while others are still to make a decision. After switchover, some Member States indicate a preference for using the digital dividend for enhancing the broadcasting service, while others express a preference for keeping the choice open or have not formulated an approach as to the foreseen use of the digital dividend.

3. What are the constraints arising in your country from the current or future use of the;
 - i) UHF band
by primary services other than broadcasting?

The need to protect existing analogue and digital television broadcasting services in the UHF band is a general constraint on the future use of the band.

A number of Member States also indicated the constraints relating to the need to protect the Radio Astronomy service in channel 38, and mobile/fixed services used for military applications in some of the channels above channel 60.

The upper part of the UHF band (above channel 55) is extensively used by other primary services (Aeronautical Radionavigation and fixed services) in Russia, Belarus and Ukraine, which creates significant constraints on a large part of the territories of countries in the Eastern part of the EU in this part of the band.

Other, more localised constraints were also identified, affecting a few countries (i.e. channel 36 in UK and channels 67-69 in the Czech Republic, which are used for aeronautical radionavigation).

ii) VHF band

by primary services other than broadcasting?

The need to protect existing analogue television and digital audio broadcasting services in the VHF band is a general constraint on the future use of the band.

A general constraint arises from the need to protect the band adjacent to channel 12, which is used in most European countries for aeronautical mobile services.

More localised constraints were also identified, affecting a few countries (i.e. channel 12 in France, where it is used for fixed and mobile services for military and PPDR, and channels 5 to 9 in the UK, where they are used for PMR).

4. Do you currently use the UHF band or VHF band for the provision of services ancillary to broadcasting? What are your plans for the future use of these bands by such services?

Practically all Members States and adjacent countries are currently using the UHF band for services ancillary to broadcasting and have indicated a continuing need for such a use, on a secondary basis.

Most countries are also using the VHF band and intend to continue such a use, on a secondary basis.

ITU RRC06

5. How many of the GE06 layers do you intend to use;
- i) in the UHF band for the provision of television services?
 - ii) in the VHF band for the provision of television or radio services?
- a. with fixed rooftop reception (RPC1)
 - b. with mobile reception (RPC2/4)
 - c. with portable indoor reception (RPC3/5)
 - d. for other services?

Most Member States considered it premature at this stage of initial development of digital terrestrial television, to draw conclusions on the expected use of these bands after analogue switchover. The table below provides the number of layers received by each country at RRC-06.

Reference network configuration	UHF			VHF			
	DVB-T RPC-1	DVB-T RPC-2	Other primary services	DVB-T RPC-3	T-DAB RPC-4	T-DAB RPC-5	Other primary services
AUT		7 layers		1 layer (RPC-2) possible usage for DAB		3 layers	
BEL		7 layers		1 layer (RPC-2)		3 layers ⁷	
CZE	7 layers		recently 3 channels, reduced in coming years	1 layer	3 layers		
DNK		7 layers	-	1 layer (RPC-2)	-	3 layers	-
D		7 layers	6 channels (military usage) 1 channel (RAS)	1 layer		3 layers	
E	12 layers			1 layer		5 layers	

⁷ Only 1 regional T-DAB-Layer for the region of Brussels and the Germanspeaking community; 3 T-DAB-Layers for the French Community and 3 T-DAB-Layers for the Flemish community.

	UHF			VHF			
F	6 layers	1.85 layers	4 channels	0-1 layer	1 layer	2-6 layers	
FIN		7 layers		2 layers			
G	8 layers		1 channel (ch 36)			4 layers	PMR
HNG		7 layers		1 layer (RPC-2)		3 layers	
HOL		7 layers	1 channel	0-1 layer		3-7 layers	LM SAP/SAB
I	8 layers			2 layers		1 layer	
IRL	8 layers			1 layer		5 layers	
LIE		7 layers				7 layers	
LTU		8 layers		1 layer		3 layers	
LTV		7 layers		1 layer (RPC-2)	1 layer	3 layers	
NOR	7 layers			1 layer		4 layers	
POR	7 layers	3 layers		1 layer	6 layers		
ROU		7 layers		1 layer		2 layers	
S	7 layers			1 layer	4 layers		
SUI		7 layers				7 layers	
SVK		7 layers		1 layer		3 layers	
SVN		7 layers		1 layer		3 layers	

Digital Dividend

6. Do you intend to use
- i) the UHF band
- for the provision of multimedia services?
- a. To what extent (How many layers? What percentage of population is intended to be covered?)
 - b. In which channels?
 - c. With which technologies?

Practically all Member States expressed intention to use the UHF band for the provision of multimedia services, particularly mobile TV reception by hand held terminals (e.g. DVB-H), or have reported an interest from operators or market actors in such a use.

A majority of Member States however, have not yet made a decision in this matter. Others indicate their intention to deploy from 1 to 7 UHF layers, ranging from 50% of population to nation wide.

Only a one administration (ROU) has made a decision at this point on which channels will be used for this purpose. A few administrations/Member States indicated a preference for the use of channels below 55.

About half of Member States/administrations that expressed a view indicated their intention to use DVB-H. Others have not taken a decision or intend to provide opportunity for a broader range of technologies.

- ii) the VHF band
for the provision of multimedia services?
 - a. To what extent (How many layers? What percentage of population is intended to be covered?)
 - b. In which channels?
 - c. With which technologies?

A number of Member States intend to use the VHF band for the provision of multimedia services, or have reported an interest from operators or market actors in such a use, while others have indicated that no decision has been made.

A majority of Member States have not yet made a decision in this matter. A few indicated their intention to deploy from 1 to 7 VHF layers, ranging from 60% of population to nation wide.

No preference has been expressed for any sub-band of the VHF band for this purpose.

Most Member States providing a response indicate a range of possible technologies (e.g. T-DAB, T-DMB, eDAB, DxB).

- 7. What is your preferred sub-band (frequency range) for harmonised downlink use by the mobile/fixed service as part of the digital dividend;
 - i. in the UHF band?
 - ii. in the VHF band?

GE-06 has harmonised the whole UHF and VHF bands for broadcasting and provided a mechanism whereby countries may operate mobile/fixed downlinks. The procedures contained in the GE-06 Agreement, together with the declaration signed by European and African countries (declaration n°42), establish a regulatory framework which enables any such services to be offered within the envelope of the characteristics of the allotments/assignments in the Plan.

Member States did not indicate definite preference for any sub-band, with the possible exception of preferably using channels below channel 55 for multimedia.

- 8. Do you intend to authorise the provision of mobile/fixed uplink transmissions;

- i. in the UHF band?
 - ii. in the VHF band?
- a. In what frequency range?
 - b. How and when?

No Member State has yet come to a decision/intention to authorise the provision of mobile/fixed uplink transmissions in UHF or VHF bands. Several Member States have indicated their willingness to consider, or not to preclude that possibility in the future, while others do not intend to authorize such transmissions.

9. Do you envisage to authorise other services then mobile multimedia or mobile/fixed services ?

From the responses received, different interpretations were taken as to regulatory fit of multimedia. Some administrations regarded it as mobile TV and an extension of broadcasting, while others considered multimedia as an extension of cellular 3G services.

Apart from fixed reception broadcasting, which is currently used in both UHF and VHF bands, and obviously cannot be ruled out for the future, Member States generally did not identify other potential uses than mobile multimedia or mobile/fixed services (including PPDR). Some Member States/administrations indicated their preference for flexible licences.

10. In order to best facilitate the use of UHF band for new (multimedia or mobile/fixed) services without the need for a replanning conference or extensive bilateral negotiations, to what extent would it be possible for you to reshuffle if needed the channels between the various layers received by your country as part of GE-06 Agreement ?

These issues are very complicated and unlikely to be resolved before switchoff.

Due to the channel grouping structure, used in developing the Irish digital plan, any spectrum released would not form a contiguous block but would be in small blocks spread across bands IV & V.

The scenarios listed are all based on there being no re-planning of the RRC06 plan. Such replanning may be necessary and should not be excluded. Some administrations however indicated that any future reshuffling of the frequencies under consideration would be extremely difficult.