



## **Reallocation of Spectrum Bands with Insurance and Compensation ----Proposal of a New System**

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Beyond Property v. Commons Dimension  
For a New Spectrum Management System

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# I. Introduction and Background

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## A. Radiowave resources

## B. History

## C. Management of spectrum



## A. Radiowave resources

### 1. Physical properties

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#### a. radiowave spectrum:

**3KHz ~ 300GHz**

#### b. transmission of energy and signals



## **A. Radiowave resources**

### **2. Technological and economic properties(1/5)**

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**a. natural resource which is**

**non-reproducible**

**non-depletable**



## **A. Radiowave resources**

### **2. Technological and economic properties(2/5)**

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**b. a “space-type” resource**

**like land as a resource**

**terrestrial spectrum:**

**3-dimensional space**

**satellite-to-earth spectrum:**

**4-dimensional space**



## **A. Radiowave resources**

### **2. Technological and economic properties(3/5)**

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#### **c. size and boundary**

**physical capacity of a piece of  
spectrum resource:**

**given and fixed**



## **A. Radiowave resources**

### **2. Technological and economic properties(4/5)**

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#### **d. utilization**

**needs capital equipment**

**(e. g., transmitters and receivers)**

**technological capacity**

**can be increased by**

**technological progress**



## **A. Radiowave resources**

### **2. Technological and economic properties(5/5)**

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#### **e. externalities**

**positive externality:**

**economies of scale**

**band-wise and area-wise**

**negative externality:**

**interferences, congestions**



## **B . History**

### **1. Beginning of spectrum use**

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**early 20th century:**

**maritime navigation**

**military use**



## **B . History**

### **2. Development**

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**expansion of spectrum uses**  
**radar, TV, wireless telephony,**  
**etc.**

**expansion of spectrum frontier:**  
**VHF, UHF, high-frequency band**



## **B . History**

### **3. Current situation**

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**exhaustion of spectrum frontier**  
**shortage of useful spectrum bands**  
**(such as VHF, UHF) in urban areas**  
**spectrum now has economic value**



## **C . Management of spectrum**

### **1. Management bodies (1/2)**

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#### **a. international organizations**

**ITU**

**Overall allocation of spectrum bands**



## **C . Management of spectrum**

### **1. Management bodies (2/2)**

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#### **b. national government**

**allocation in detail**

**technological specifications**

**assignment of spectrum blocks(licensing)**



## **C . Management of spectrum**

### **2.Objectives of management (1/2)**

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#### **a. before spectrum shortage emerges:**

**prevention from interferences**

**promotion of use with positive externalities**



## **C . Management of spectrum**

### **2.Objectives of management (2/2)**

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#### **b. after spectrum shortage:**

**efficient utilization of spectrum resources**





## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (1/8)**

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#### **a. exclusive use**

**spectrum block is assigned exclusively to a single user**

**licensed for a limited period of time but renewable**

**systems for this use:**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (2/8)**

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#### **a. exclusive use**

**(1) command and control (traditional system)**

**repeated renewals**

**no rental or lease fees**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (3/8)**

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#### **a. exclusive use**

##### **(2) market mechanism**

###### **(a) spectrum as a property**

**auction at initial assignment**

**secondary property markets**

**secondary lease markets**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (4/8)**

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#### **a. exclusive use**

##### **(2) market mechanism**

###### **(b) competitive lease and renewal by government**

**some protection of incumbents at renewal**

**secondary markets for lease rights**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (5/8)**

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#### **b. club use**

**spectrum block is assigned to multiple users (with licenses)**

**unlimited or restricted entry**

**systems for this use:**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (6/8)**

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#### **b. club use**

**(1) command and control**

**for unlimited or restricted entry**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (7/8)**

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#### **b. club use**

##### **(2) some market mechanism**

##### **for restricted entry**



## **C . Management of spectrum**

### **3. Various modes and institutions for spectrum assignment (8/8)**

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#### **c. commons (free) use**

**spectrum block is open to the public for**

**free use**



## **C . Management of spectrum**

### **4. institutions for spectrum allocation (1/2)**

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#### **a. international allocation**

**negotiations in ITU**

**conflicting interests to member countries**

**time-consuming and costly process**

**reallocation is often delayed**



## **C . Management of spectrum**

### **4. institutions for spectrum allocation (2/2)**

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#### **b. domestic allocation**

**command and control by a national  
government**

**vested interests of incumbent users**

**reallocation is time-consuming**



## **II. Reallocation with Insurance and Compensation (RIC) (1/2)**

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- A. Outline**
- B. Selection of spectrum bands to be reallocated  
(to be done by the government)**
- C. Determination of the rate for compensation  
premiums (to be done by the government)**
- D. Implications of RIC as an insurance**



## **II. Reallocation with Insurance and Compensation (RIC) (2/2)**

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- E. Possibility of speculative behavior by users**
- F. Implications of RIC to income distribution**



## II. A. Outline

### 1. spectrum users (1/2)

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**equivalent to subscribing to an insurance  
plan covering the cost of reallocation**

**choose and register an amount of  
compensation**

**pay an insurance premium  
(compensation premium) to  
government**



## II. A. Outline

### 1. spectrum users (2/2)

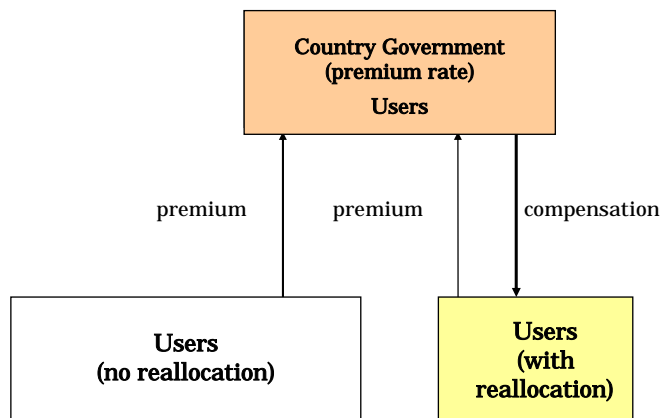
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**(compensation premium)**

**= (compensation premium rate) \*  
(compensation amount declared)**



## Insurance-Compensation for Reallocation



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## II. A. Outline

### 2. government

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**determines a rate of compensation premium**

**so as to balance the income from premiums  
and the outlay for compensations**

**selects spectrum bands to be reallocated**

**pays compensation to users with reallocation**



## **II. B. Selection of spectrum bands to be reallocated**

### **1. Establishing a new allocation**

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**new objective and a mode of use**

**the size of spectrum bands to be reallocated for  
the new objective**

**to be determined by government**

**decision would be easy with market-oriented  
assignment**



## **II. B. Selection of spectrum bands to be reallocated**

### **2. Determination of the location of spectrum bands to be reclaimed for reallocation**

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**minimization of the total amount of  
compensations for reallocation**

**consideration of externalities**

**economies of scale in using the spectrum bands  
reclaimed**



## **II. C. Determination of the rate for compensation premiums**

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**maintenance of the long-run balance between  
the premium income and the compensation  
outlays**

**minimization of the average annual changes in  
the premium rate**

**an algorithm for rate adjustments  
(left for research in the future)**



## **II. D. Implications of RIC as an insurance**

### **1. Fair insurance to spectrum users in the long run**

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**(probability of spectrum reallocation to users)**

**= ( average annual premium rate).**



## **II. D. Implications of RIC as an insurance**

### **2. Rational behavior of spectrum users**

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**complete insurance:**

**the level of utility is unchanged**

**regardless whether the spectrum band is  
reallocated or not**

**maximization of the expected utility level**



## **II. E. Possibility of speculative behavior by users**

### **1. Spectrum “hold-up”**

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**declaring an extremely large amount of  
compensation to spectrum with high  
probability of reallocation**

**utilization of positive externality between  
contiguous spectrum blocks**



## **II. E. Possibility of speculative behavior by users**

### **1. Spectrum “hold-up”**

---

**possibility of successful hold-up is decreased  
by RIC**

**declaring a large amount of compensation  
means an increase in premium payment  
decreases the probability of reallocation**



## **II. F. Implications of RIC to income distribution**

### **(1/2)**

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**the social cost of spectrum reallocation is**

**the sum of the costs incurred to users  
with spectrum reallocation**

**borne by all spectrum users**



## **II. F. Implications of RIC to income distribution (2/2)**

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**a fair outcome since spectrum  
shortage arises from the  
demand for spectrum resources  
by all users**



## **III. RIC and Spectrum Assignment**

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- A. Club or commons**
- B. Market mechanism**
- C. Command and control**



### **III. A. Club or commons**

#### **1. Allocation and assignment:**

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**government allocates a band for club or  
commons use**

**assignment to multiple users or open to the  
public**

**RIC works well.**



### **III. A. Club or commons**

#### **2. Club or commons users**

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**each declares and registers a compensation  
amount**

**pays compensation premium**

**this may be done at the time a user buys a  
device for using the club or commons band**

**receives compensation if the band is reallocated  
and the device becomes worthless**



**III. A. Club or commons**  
**3. Government**

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**(the total amount of compensations to be paid at reallocation)**

**= (the sum of the declared compensations by all users of the reclaimed band)**

**Lindahl-Samuelson valuation of public good**



**III. B. Market mechanism**  
**1. Allocation and assignment (1/2)**

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**government allocates a band for exclusive use**

**assignment by means of a market mechanism**

**private property (to be used within the allocation restrictions)**

**traded or leased**



### **III. B. Market mechanism**

#### **1. Allocation and assignment (2/2)**

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**government property**

**leased competitively to users**

**RIC works well.**



### **III. B. Market mechanism**

#### **2. Spectrum users**

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**declare compensations and pay premiums**

**decision on compensation can be made by  
considering market values of spectrum**

**(e.g., the estimated cost of acquiring a  
replacement spectrum)**

**receive compensations at reallocation**





### **III. B. Market mechanism**

#### **3. Government**

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**decision on reallocation can be made  
on market values of spectrum**



### **III. C. Command and control**

#### **1. Allocation and assignment**

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**government allocates a band for exclusive  
use**

**assignment on first-come base, comparative  
hearings, or random selection**

**RIC works, but not well.**



### **III. C. Command and control**

#### **2. Spectrum users**

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**declare compensations and pay premiums**

**decision on compensation need to be  
done with uncertainty**

**receive compensations at reallocation**



### **III. C. Command and control**

#### **3. Government**

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**decision on reallocation need to be  
done by discretions**



## **IV. Discussions of RIC (1/2)**

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- A. Economic meaning of compensations**
- B. Decision by government on the size of spectrum bands to be reallocated**
- C. Decision by government on selection of spectrum bands to be reallocated**
- D. Determination of the amount of compensation by users**



## **IV. Discussions of RIC (2/2)**

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- E. Introduction of multiple reallocation periods**
- F. Introduction of (partial) compensation in kind**



#### **IV. A. Economic meaning of compensations**

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**the supply price of the right of using a  
spectrum band with respect to reallocation**

**the value of spectrum to incumbent users**

**RIC functions as a price mechanism**

**a means to calculate the spectrum value**



#### **IV. B. Decision by government on the size of spectrum bands to be reallocated**

##### **1. Criteria for reallocation (1/2)**

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**a band should be reallocated  
from low-efficiency use to  
high-efficiency use**

**a band should be reallocated if  
the efficiency-improvement  
index is greater than 1, where**



#### **IV. B. Decision by government on the size of spectrum bands to be reallocated**

##### **1. Criteria for reallocation (2/2)**

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**(the efficiency-improvement index) =  $(B - C) / A$**

**A = (the present value of a band with the current use)**

**B = (the present value of the band with a new use)**

**C = (the compensation to be paid for reallocating the band)**



#### **IV. B. Decision by government on the size of spectrum bands to be reallocated**

##### **2. Spectrum band is assigned with a market mechanism**

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**the present value of a band may be calculated by using market prices**

**government can rely on market data for making decisions on reallocation**



**IV. B. Decision by government on the size of  
spectrum bands to be reallocated**

**3. Spectrum band is assigned with a command and control**

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**the present value of a band need to be  
estimated in some way**

**government need to rely on discretions for  
making decisions on reallocation**

**likely disputes, difficulties, and delays in  
reallocation**



**IV. C. Decision by government on selection of spectrum  
bands to be reallocated**

**1. Selection of bands to be reallocated**

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**minimization of compensation outlays**

**consideration of positive externality**

**selection of bands contiguous area-wise  
and/or frequency-wise**



**IV. C. Decision by government on selection of spectrum  
bands to be reallocated**  
**2. Prevention of speculative behavior by users (1/4)**

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**a. speculative behavior**

**declare a very high amount of compensation to  
a band which is**

**likely to be reclaimed**

**low compensations attached by other users**



**IV. C. Decision by government on selection of spectrum  
bands to be reallocated**  
**2. Prevention of speculative behavior by users (2/4)**

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**b. prevention of speculative behavior (1/2)**

**disclose information on the amount of  
compensations declared by users**

**announce a tentative decision on selection of  
bands for reallocation, and**



**IV. C. Decision by government on selection of spectrum  
bands to be reallocated**  
**2. Prevention of speculative behavior by users (3/4)**

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- b. prevention of speculative behavior (2/2)**  
**give ample time for users to readjust the  
amount of compensations,  
before executing a final decision**  
**impose restrictions on adjusting the amount  
of compensations by users**



**IV. C. Decision by government on selection of spectrum  
bands to be reallocated**  
**2. Prevention of speculative behavior by users (4/4)**

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- c. designing a mechanism (algorithm)  
for avoiding speculative behaviors  
(research in the future)**





#### IV. D. Determination of the amount of compensation by users

##### 1. Non-speculative decision

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**(the amount of compensation to be declared)**

**= (the present value of future incomes with the  
current business without reallocation)**

**– (the present value of future incomes with a  
business after reallocation)**

**+ Q, where**

**Q = (the once-and-for-all cost of changing business  
because of reallocation)**



#### IV. E. Introduction of multiple reallocation periods

##### 1. Reallocation period

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**the length of time from the decision of  
reallocation to the execution of reallocation**

**multiple reallocation periods**

**give flexibility to users and government**



**IV. E. Introduction of multiple reallocation periods**  
**2. An example of RIC with five reallocation periods (1/3)**

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**a. spectrum users**

**declare an amount of compensation for  
each of the 5 reallocation periods  
(say, of 1 to 5 years) and pay premium**



**IV. E. Introduction of multiple reallocation periods**  
**2. An example of RIC with five reallocation periods (2/3)**

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**b. government**

**sets premium rate  
so as to balance the long-run RIC budget  
a rate for each of the 5 periods, or  
a single rate to be applied to each period**



**IV. E. Introduction of multiple reallocation periods**  
**2. An example of RIC with five reallocation periods (3/3)**

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- c. selection of bands to be reallocated by government**  
**gradual execution of reallocations**  
**selection of a reallocation period for each band to**  
**be reclaimed**  
**minimization of the present value of compensations**  
**to be paid during the coming 5 years**  
**selection algorithm:**  
**for research in the future**



**IV. F. Introduction of (partial) compensation in kind**  
**1. Compensation in kind**

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**allocation of a spectrum band, of which a**  
**block may be assigned to users with**  
**reallocation**  
**users may receive for reclaimed band**  
**monetary compensation and/or**  
**spectrum block in another band**  
**useful in the command and control mode**



## IV. F. Introduction of (partial) compensation in kind

### 2. Example of compensation in kind (1/2)

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#### (a) data

**X** = (the size of spectrum block assigned to a user before reallocation)

**Y** = (the size of spectrum block assigned to the user as compensation in kind)

$$(Y \leq X)$$

#### (b) government

specifies an upper bound  $\check{Y}$  for compensation in kind Y



## IV. F. Introduction of (partial) compensation in kind

### 2. Example of compensation in kind (2/2)

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#### (c) users

declare an amount of monetary compensation for reallocation of X

choose a Y ( $\leq \check{Y}$ ) and receive

(the amount of monetary compensation)

$$= (\text{the declared compensation for X}) * (X - Y) / X$$



## **V. RIC for International Reallocation of Spectrum (IRIC)**

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- A. International reallocation of spectrum  
– current state**
- B. Outline of IRIC**
- C. ITU and member-country (1/3)**
- D. ITU and member-country (2/3)**
- E. ITU and member-country (3/3)**



### **V. A. International reallocation of spectrum – current state**

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**negotiations in international organizations  
(such as ITU)**

**conflict of interests to member countries**

**difficulty in negotiations**

**delay in agreeing on reallocation**



## **V. B. Outline of IRIC**

### **1. Government of member countries**

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**plays to ITU the role of users in domestic RIC**

**selects an amount of compensation for each spectrum band**

**pays compensation premium to ITU**

**receives compensation for reallocated bands**

**the payment and receipt by a member country with ITU need not balance**



## **V. B. Outline of IRIC**

### **2. ITU (international organization)**

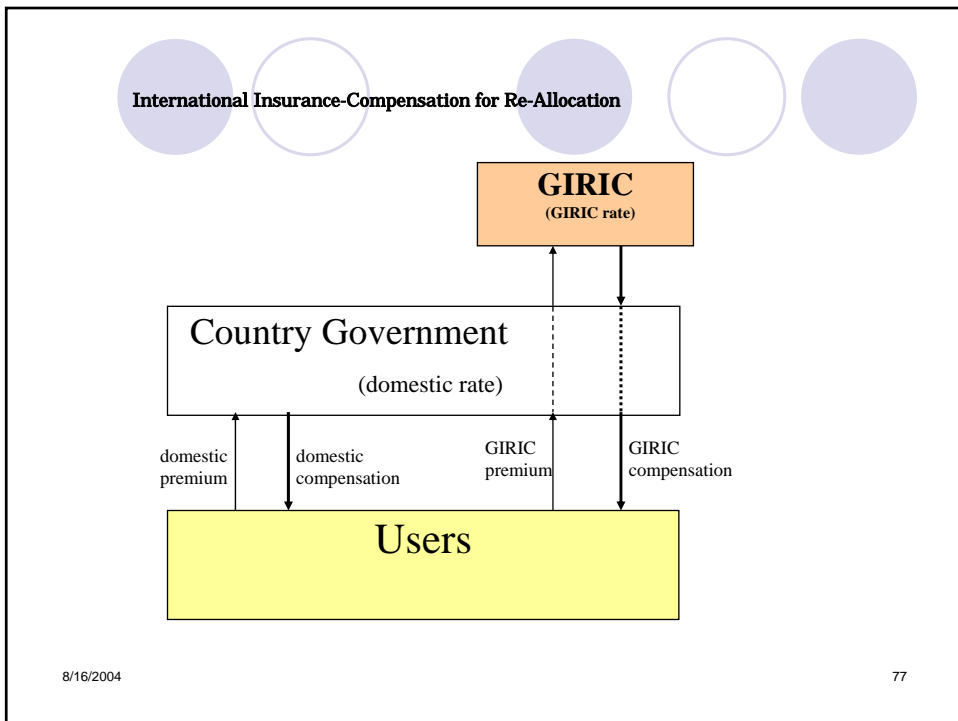
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**plays to member countries the role of government in domestic RIC**

**sets a premium rate so as to balance the income and payment to ITU in the long run**

**pays compensation to member countries for reallocated bands**





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**V. C. ITU and member-country (1/3)**


**1. Outline**

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**ITU adopts IRIC**

**member countries adopt RIC**

**IRIC and RIC function well together.**

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## V. C. ITU and member-country (1/3)

### 2. Action by member countries to ITU

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**aggregate the domestically declared  
compensations for each band and register the  
sum with ITU**

**apply the ITU premium<sup>̄</sup> rate to domestic users**

**pay the sum of domestic premiums to ITU**

**distribute the compensation received from ITU  
to domestic users as declared**

**the role of domestic government becomes  
transparent**



## V. D. ITU and member-country (2/3)

### 1. Outline

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**ITU adopts IRIC**

**member country does not adopt RIC**

**domestic reallocation done by  
command and control**





## **V. D. ITU and member-country (2/3)**

### **2. Action by member country to ITU**

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**follows IRIC rules at ITU**

**declares an amount of compensation for each band**

**need to aggregate the preferences of domestic users with regard to reallocation in some way**

**the amount of work is of the same order as in the current situation**



## **V. E. ITU and member-country (3/3)**

### **1. Outline**

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**ITU does not adopt IRIC**

**negotiation for reallocation by member countries continues**

**some member countries adopt RIC domestically**



## **V. E. ITU and member-country (3/3)**

### **2. Member countries with domestic RIC**

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**may form a group within ITU for spectrum  
reallocation (GIRIC)**

**execute IRIC within GIRIC**

**coordinate for negotiations in ITU**

**offer to ITU a reallocation plan agreed upon  
within GIRIC**

