

**Designing a Mechanism for Reallocating Spectrum  
as a Resource with Vested Right, Sunk Cost, and Externalities**

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**I. Introduction**

**A. Objective of this paper**

design and analyze an economic mechanism of spectrum trade for efficient use  
**extended market mechanism (EMM)**

**B. Strategy for the work**

two-step designing

- (1) to design an “ideal” system from scratch
- (2) to design transition process from current state to ideal system

**C. Properties of the ideal system**

- (1) a process of stepwise reallocation of spectrum
- (2) each step Pareto-improves spectrum allocation (no user shall be hurt)

**II. Spectrum as an economic resource**

**A. What is spectrum?**

a space resource with limited capacity  
no depletion, no depreciation  
can be used in exclusive or shared mode  
externalities, positive and negative  
technological progress increases efficiency

**B. Division of spectrum into bands/blocks**

band: a segment of one-dimensional frequency space (Fig. 1)

block: (of the terrestrial spectrum) (Fig. 2)  
a subset of three-dimensional space composed by the frequency space and the surface of the land (Fig. 3)

**C. Incumbent users of spectrum blocks**

obtain returns from using block(s)

investment made in the past

sunk cost

cost of holding block(s)

no physical cost

there may be institutional cost

ex.: spectrum usage fee

local monopoly

**D. Potential users of spectrum blocks**

may form a plan for using block(s)

usage plan

returns forecast

may offer demand price for block(s)

ex.: through auction

**E. Pareto-improving reallocation of block(s) (1)**

For block(s) being reallocated,

(returns from the current use)

< (returns from a potential use)

**F. Pareto-improving reallocation of block(s) (2)**

For both incumbent and new users,

(returns before reallocation)

$\cong$  (returns after reallocation)

### **G. Ordinary market mechanism (MM) for reallocation**

Offer by potential users:

- may be done with combinations of blocks
- considering (positive) externalities

Response by incumbent:

- will execute power of local monopoly
- strategic use of (positive) externalities
- may quote an extremely high price for yielding a block

MM will not function for spectrum reallocation

### **H. Reasons that MM does not function for spectrum reallocation**

(1) conditions for MM to function effectively:

- a. perfect information
- b. competition with both demand and supply
- c. goods to be traded: homogeneous or with perfect substitutes
- d. no externalities
- e. individuals have incentive to trade

(2) with spectrum as an object of trade:

- a. (perfect information) may be assumed
- b. (competition) not satisfied; local monopoly with supply
- c. (perfect substitutes) do not exist; spectrum block is unique areawise and frequencywise
- d. (externalities) exist, positive and negative
- e. (incentive of trade) weak with incumbents because of sunk cost and zero holding cost

## **III. Overview of EMM, proposed**

### **A. Bill of spectrum rights and responsibilities (proposed)**

- (1) Spectrum is a property owned by the society collectively.
- (2) Spectrum may be used exclusively by a user for an indefinite period; the right to use spectrum is by no means permanent.

- (3) The user of spectrum shall pay a usage fee to the government.
- (4) The user shall yield the right of using spectrum when requested with a compensation which exceeds the amount specified by the user himself/herself prior to such a request.
- (5) Reallocation of spectrum rights shall be Pareto-improving. Further, if more than one reallocation plans are contemplated, the plan giving the greatest improvement of spectrum use in monetary term shall be adopted.

**B. Division of spectrum management (Fig. 4)**

- (1) government:
  - specification of bands, blocks
  - technological requirements
  - formation of *block structure (groups)* (→ III.C)
- (2) EMM:
  - specifies block users

**C. Block structure (Fig. 5)**

tree-type (hierarchical) grouping of blocks

a spectrum *group* is either

- a block, or
- a collection of blocks, or
- a collection of groups.

(may be defined mathematically as a *tree*, a subcategory of *graphs*, where end nodes (leaves) are spectrum blocks)

**D. Allocation and reallocation of spectrum to users**

to be determined by EMM  
users: participate to EMM

- incumbents and potential users

government: regulates EMM

- does not determine spectrum users

--- this is the objective of the paper

#### IV. Functioning of EMM, proposed (Fig. 6)

##### A. Objective

to realize possible Pareto-improving reallocation of spectrum blocks  
the “speed” of improvement: to be controlled by the government

##### B. Rights and obligations of incumbents

- (1) Revelation of supply price ( $c$ ) of each group (block)

$c$ : the least amount of compensation for which incumbent agrees to yield the right of  
using the group

- (2) Payment of spectrum usage fee ( $R$ )

$$R = r C.$$

$C$ : the sum of  $c$ 's declared with top-level groups

$r$ : (annual) rate of spectrum usage fee to be determined by the government

- (3) Incumbents

may continue using a group if there is no offer  $> c$

must yield the block if there is an offer  $\geq c$

- (4) Determination of  $c$  by incumbents:

Incumbents tend to declare

a high  $c$  for continuing the use of a group

a low  $c$  for saving payment  $R$

tradeoff to incumbents

“holding up” a block or a group may be costly

- (5) Who are “incumbents”?

all users of spectrum

private, business, and government users

##### C. Rights and responsibilities of potential users

- (1) Obtain information of  $c$ 's and  $C$ 's

- (2) Make offers by showing demand price ( $D$ ) for groups (blocks) chosen

- (3) If there is no competing offer,

then potential user obtains spectrum right for paying  $D$ .

(4) If there is a competing offer,

then auction will be conducted on such groups

winning potential user obtains spectrum right for paying  $D$ .

**D. Roles of government with EMM (1): spectrum holding fee**

(1) determines a fee rate ( $r$ ):

to control the speed of reallocation

resembles to determination of discount rate by central bank

(2) receives spectrum fees ( $R$ )

**E. Roles of the government with EMM (2): market auctioneer**

(1) conducts auction for each group with  $D > c$

use combinatorial auction (computerized)

bidding rule, stopping rule

determines winning bids so as to maximize the total amount of bid price minus  $c$

(= total surplus)

(2) receives total surplus

(Figs. 7A, 7B)

**F. Roles of the government (3): collection and dissemination of information**

(1)  $c, C, D$ , auction process, auction results

(2) the state of spectrum rights:

registration

information disclosure

**G. Outcome from EMM:**

Pareto-improving reallocations will be realized gradually step by step

speed of reallocation is controlled by  $r$

**V. Secondary (indirect) users of spectrum with EMM**

**A. Commons users (Fig. 8):**

primary user: a government administrator

secondary users: general users (the public)

$C$ : the sum of all compensations declared by the users

$R$ : may be collected at purchasing a device for using a commons block  
(payment may be made together with that of insurance fees for breakage)

**B. Subscribers to service using spectrum (Fig. 9):**

ex.: mobile phone users

wireless internet users

primary user: providers, broadcasters

secondary users: subscribers, "users"

$C$ : the sum of compensations declared by the primary and the secondary users

$R$ : may be collected by primary user from secondary users to remit to government

**C. Transition to DTV in the presence of EMM**

would have been a case of reallocation of commons blocks under EMM

**VI. Introduction of reallocation as a forward trading, forward supply price**

EMM with timing of reallocation specified

ex.: reallocation  $x$  years after the current year

$x = 1, 3, 5$  and 10 years

$c, C, D, r$  to be specified for each  $x$ .

EMM is applied for each  $x$ .

actual reallocation to be done in the year  $x$ .

both incumbent and potential users will be benefited.

**VII. Preventing speculation with EMM (Figs. 10A, 10B)**

speculation is possible on a strategically positioned block wrt externalities

regulation:

impose a penalty on a steep increase in  $C$

### **VIII. Transition from the current system to EMM**

gradual transition is recommended

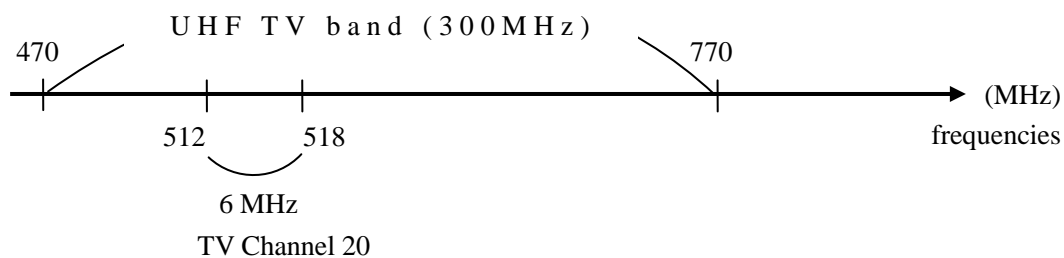
no “big bang”

set  $r$  at a level close to zero initially

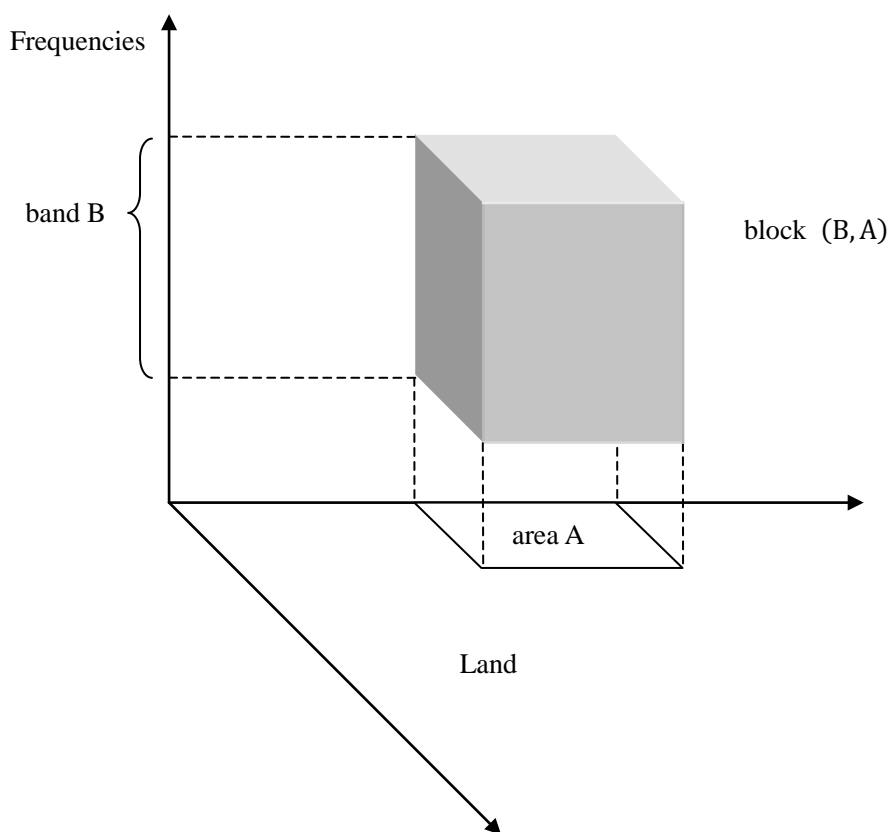
increase  $r$  gradually thereafter

decrease the rate for current spectrum fees simultaneously

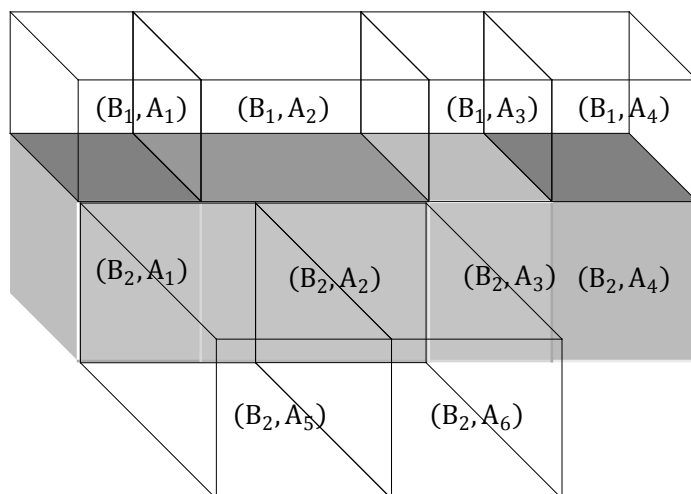




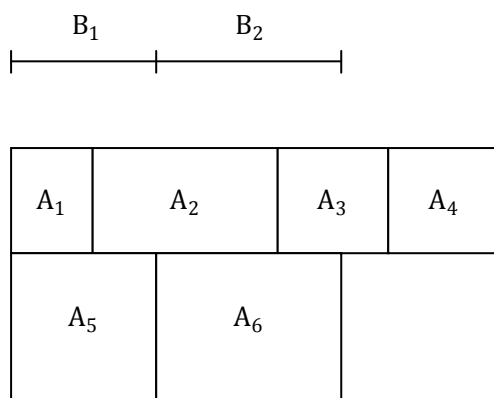
**Figure 1:** Examples of Spectrum Band in the Frequencies Axis



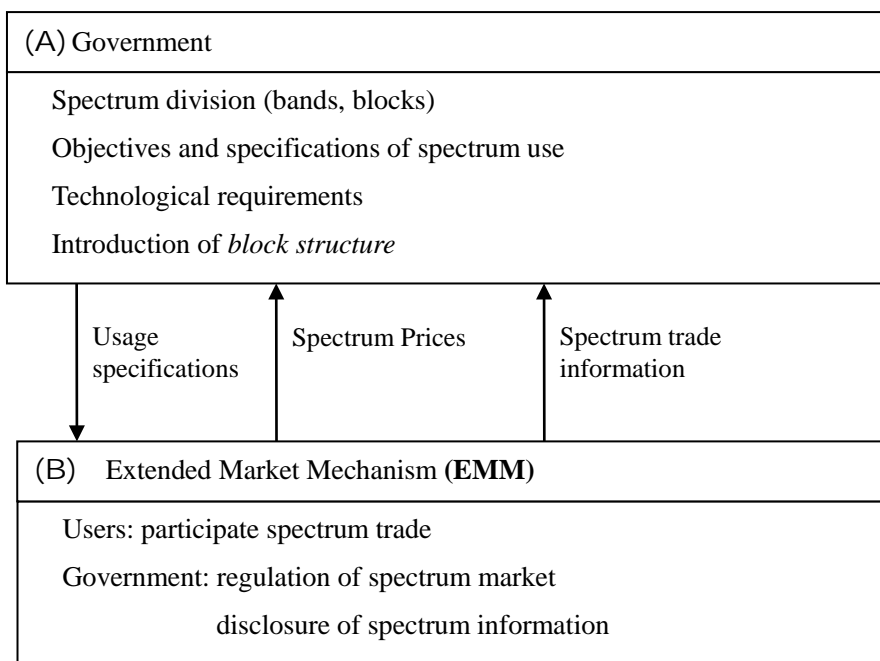
**Figure 2:** Example of Spectrum Block(B, A) in the 3-dimentional Spectrum Space



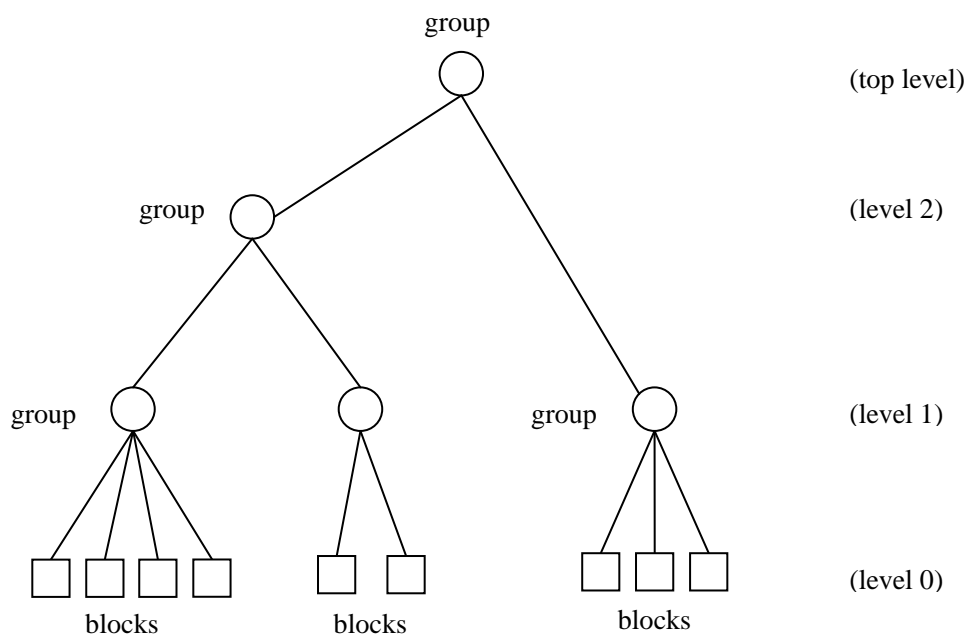
**Figure 3A:** Example of 10 Spectrum Blocks



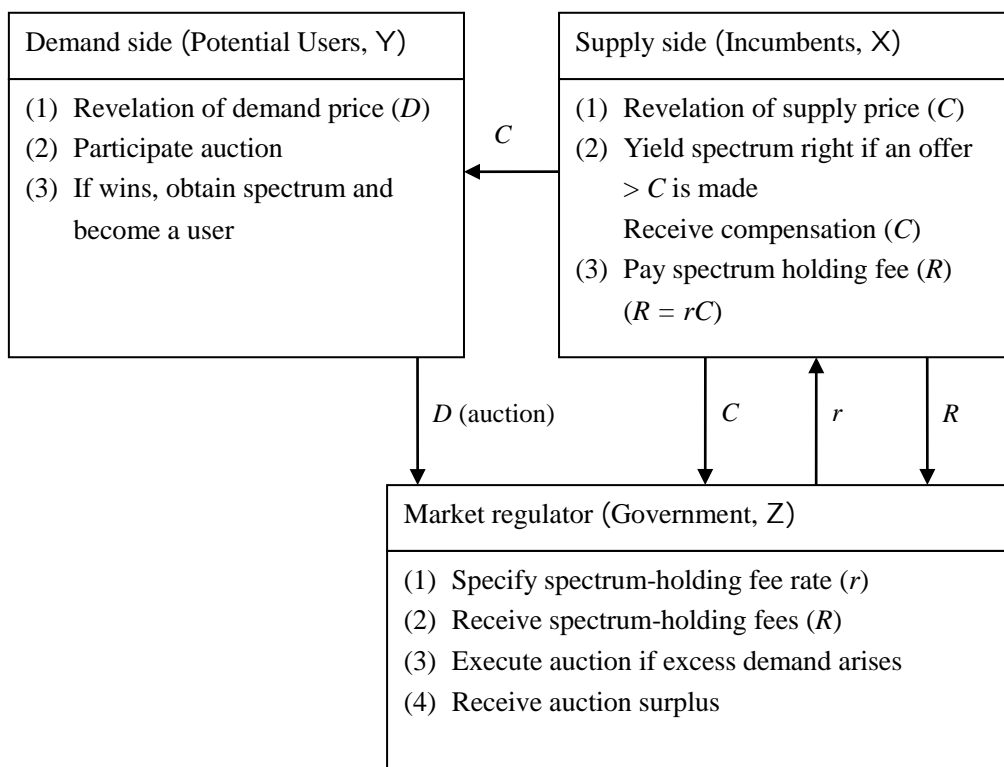
**Figure 3B:** 2 Bands and 6 Areas for the Blocks of Figure 3A



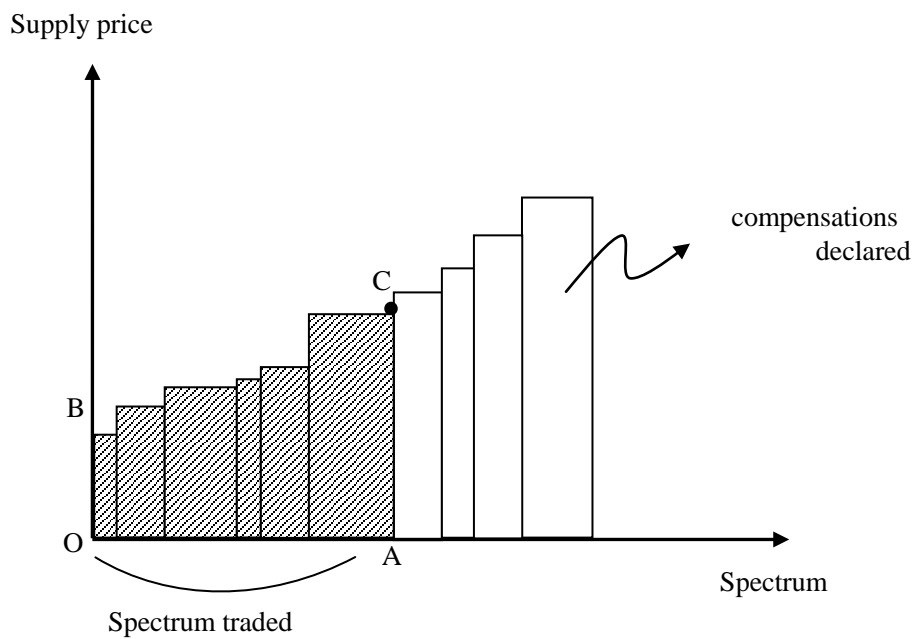
**Figure 4:** Overview of spectrum use with EMM



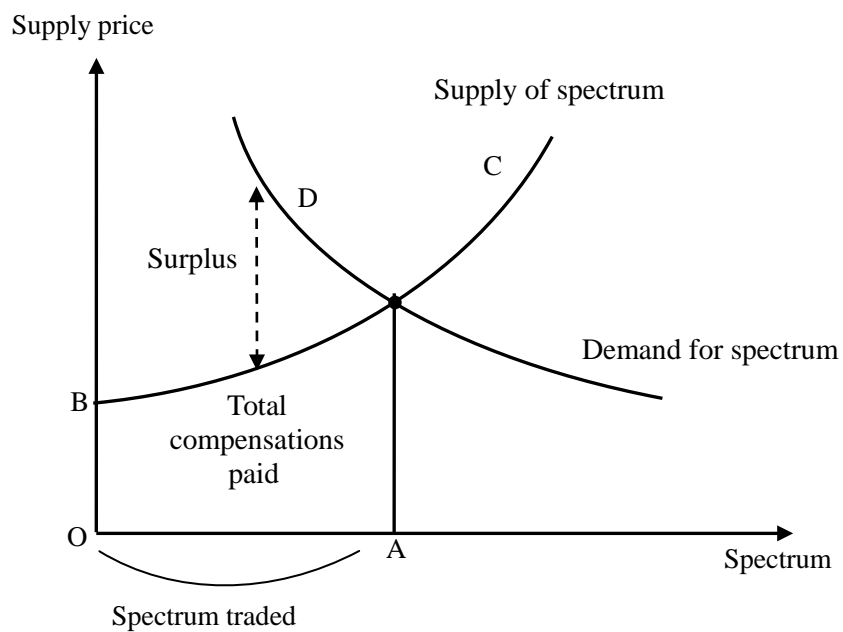
**Figure 5:** Spectrum Groups (Block Structure)



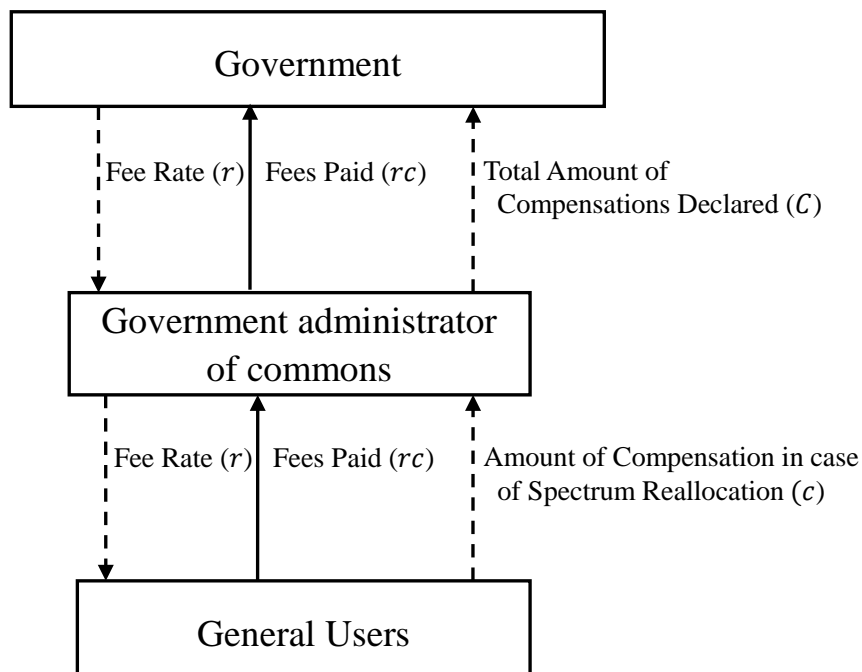
**Figure 6:** Organization of EMM



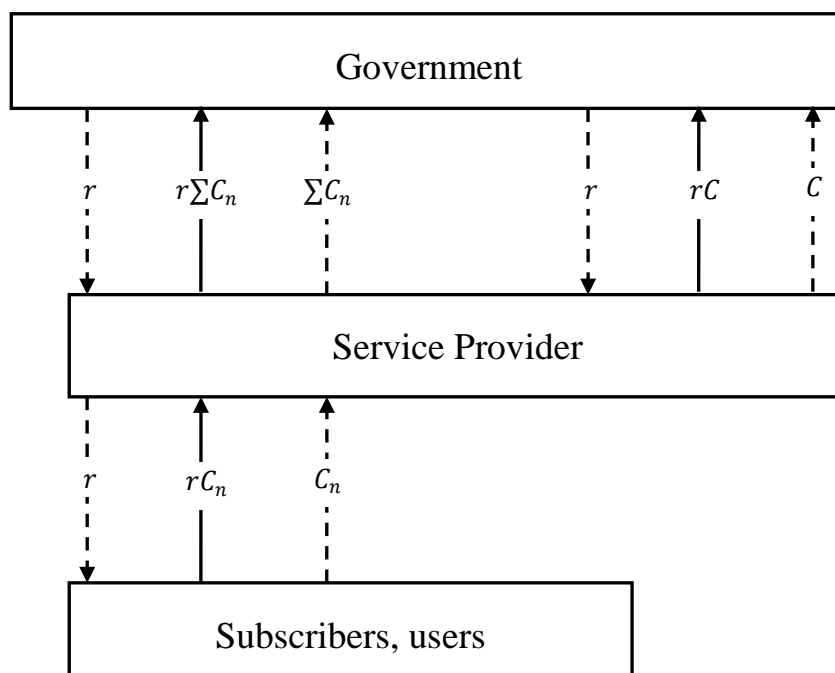
**Figure 7A:** “Supply” of Spectrum



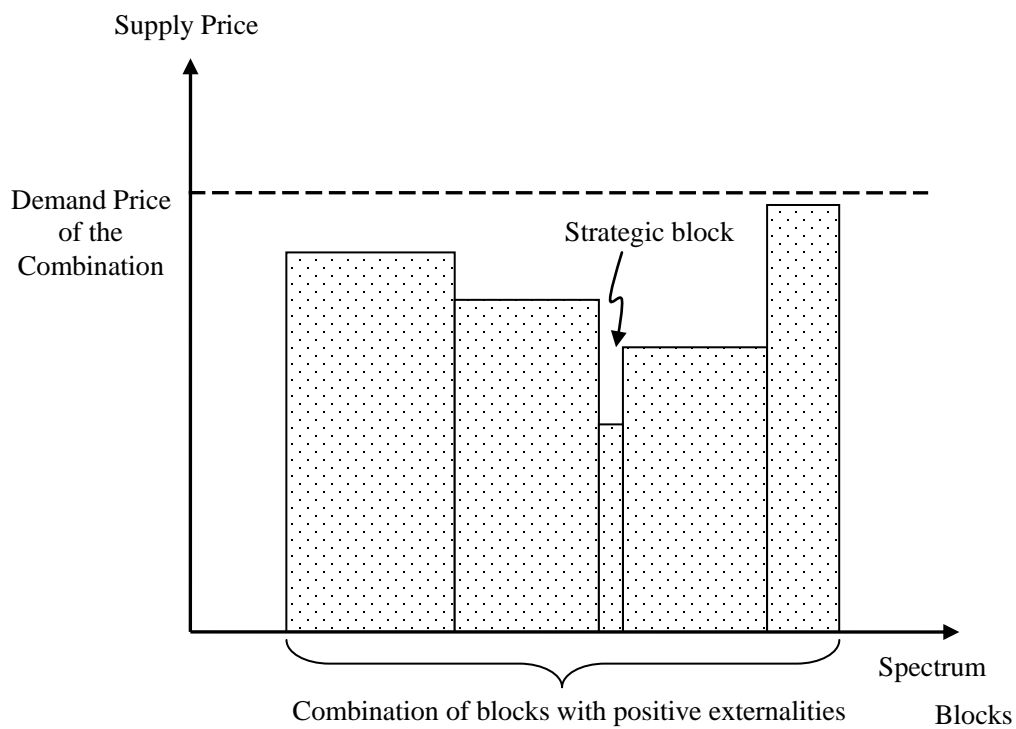
**Figure 7B:** “Demand and Supply” of Spectrum



**Figure 8:** Supply Price Revealed by Commons Users

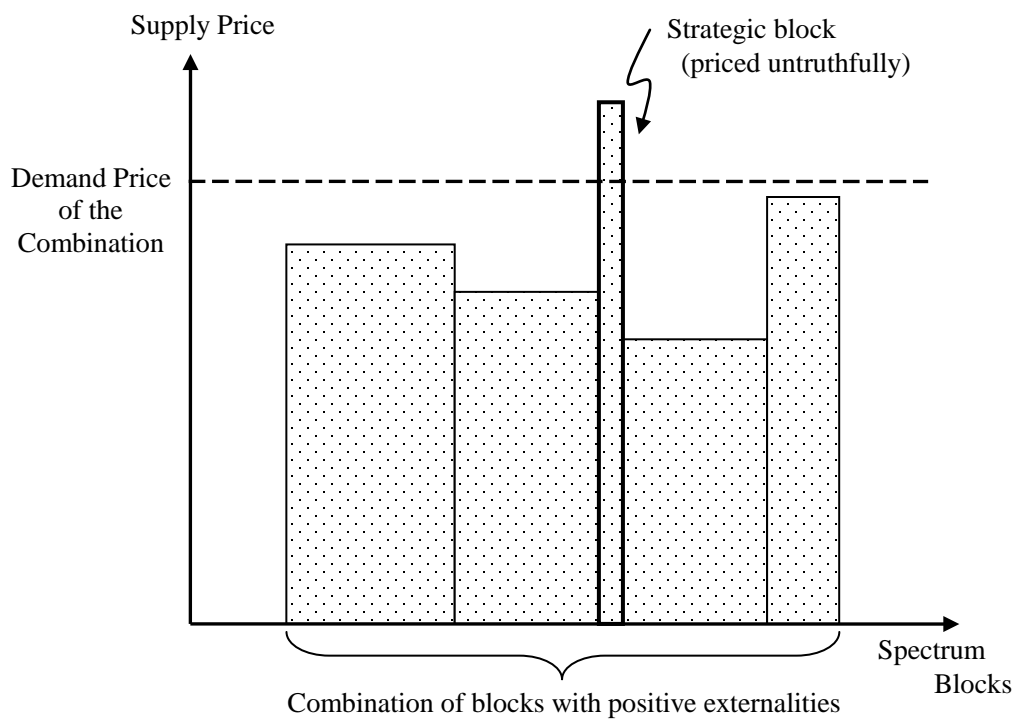


**Figure 9:** Supply Prices Revealed by a Service Provider and Subscribers



**Figure 10A:** Example of truthful supply prices





**Figure 10B:** Example of truthful and untruthful supply prices