

RECOMMENDATION ITU-R SM.1132-2*

General principles and methods for sharing between radiocommunication services or between radio stations

(Question ITU-R 45/1)

(1995-2000-2001)

The ITU Radiocommunication Assembly,

considering

- a) that efficient and effective use of the radio spectrum often requires the sharing of frequencies or frequency bands by different radiocommunication services or by radio stations;
- b) that general principles are needed for considering spectrum sharing;
- c) that methods to facilitate sharing need to be delineated;
- d) that methods to apply in specific sharing cases are recommended in a variety of ITU-R Recommendations appropriate to the specific sharing situation,

recommends

1 that administrations consider the general principles and methods described in Annex 1 for facilitating efficient and effective sharing of spectrum by multiple radiocommunication services or by radio stations.

ANNEX 1

General principles and methods related to spectrum sharing**1 Dimensions of allocation sharing**

Spectrum sharing holds the potential for increasing the efficiency and effectiveness of spectrum use. Interservice sharing exists when two or more radiocommunication services effectively use the same frequency band. Nos. 1.166 to 1.176 of the Radio Regulations (RR) define the parameters to be taken into account in frequency sharing. Interservice and intra-service sharing of spectrum are facilitated by application of sharing principles and methods that are considered on a general basis but also used in the assignment of frequencies on a station-by-station basis. Utilization of the radio spectrum is dependent on the dimensions of frequency, spatial location, time and signal separation. Any sharing of the spectrum will have to take into account one or more of these four dimensions.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 6, 7, 8 and 9 and Telecommunication Development Study Groups 1 and 2.

Sharing can be accomplished in a straightforward fashion when any two of these dimensions are in common and the third and/or fourth dimension differs by a degree sufficient to ensure that all the involved services or stations (two or more) can operate satisfactorily. Sharing can also be accomplished when services or stations have all four dimensions in common. In such cases, service sharing rules cannot ensure non-interference and individual assignments must be made on the basis of the totality of assignments already made in all of the overlapping services, so that combinations of factors can be found for individual assignments that will not interfere with each other. Generally speaking, multidimensional use of spectrum could obtain additional power/spectrum and/or orbit processing gain, even though it would make the system architecture or structure somewhat more complicated.

2 Sharing methods

Table 1 shows some of the methods which can be used to facilitate sharing, grouped in columns based on the four dimensions: frequency, spatial location, time and signal separation.

Within Table 1 some of the methods are new or innovative and may make more efficient use of the spectrum or provide flexibility. Many of these methods result from the introduction of new equipment technologies, computerization of analysis and new ideas. Some of the methods are complex, involving real-time computer controlled frequency management.

Often, the specification of particular technical parameters for equipment is necessary to implement sharing methods shown in Table 1.

2.1 Frequency separation

2.1.1 Channelling plans

It is possible to arrange channels of operation on a homogeneous or inhomogeneous basis so as to interstitially configure one or more communications systems. This means of avoiding interference must be coordinated ahead of time so that the channels are appropriately separated to take advantage of the type of modulation FEC and/or coded modulation used, the frequency domain envelope shapes, the transmitted necessary bandwidth, and receiver bandpass characteristics. This technique is appropriate for use by adjacent satellites that do not use homogeneous transponders in the geostationary-satellite orbit (GSO).

The economics of channel plan coordination are often a necessary expense of coordination required between co-primary users of the same spectrum. The burden is shared between system operators and almost always gives satisfactory results.

TABLE 1

Methods to facilitate sharing

Frequency separation	Spatial separation	Time separation	Signal separation⁽²⁾
Channelling plans Band segmentation Frequency agile systems Dynamic sharing: – dynamic real-time frequency assignment ⁽¹⁾ Frequency division multiple access (FDMA) Control of emission spectrum characteristics Dynamic variable partitioning Frequency tolerance limitation Demand assignment multiple access (DAMA) Frequency diversity	Geographical shared allocations Site separation Antenna system characteristics: – adaptive antenna (smart antenna) – antenna polarization discrimination – antenna pattern discrimination – space diversity – antenna angle or pattern diversity Space division multiple access (SDMA) Physical barriers and site shielding	Duty cycle control Dynamic real-time ⁽¹⁾ frequency assignment Time division multiple access (TDMA)	Signal coding and processing Forward error correction (FEC) Interference rejection Code division multiple access (CDMA) Spread spectrum: – direct sequence – frequency hopping – pulsed FM Interference power/bandwidth adjustments: – co-channel – dynamic transmitter level control – power flux-density (pfd) limitation and spectral power flux-density (spfd) limitation (energy dispersal) Modulation complexity Coded modulation Adaptive signal processing Antenna polarization

⁽¹⁾ Dynamic real-time frequency assignment facilitates sharing by simultaneously using frequency and time domains. Therefore, this method is shown in both columns.

⁽²⁾ These techniques for signal separation may also be applied to frequency, space and time separation technology.

2.1.2 Band segmentation (see Note 1)

The grouping of a number of channels, or the creation of a sub-band for non-channelized systems, for different users or uses of the spectrum is similar to the use of channel plans. In some situations this will be desirable because it has the advantage of minimizing or avoiding the need for coordination, while enabling multiple uses of a band. It encourages efficient use of the spectrum if additional spectrum is not available. It enables the full development of the respective services, rather than having the early or unexpected growth of one service or type of system curtail the growth of another desired service or system.

NOTE 1 – Band segmentation between radiocommunication services can be viewed as actually eliminating sharing by creating sub-allocations. In light of the fact that administrations take internationally shared allocations and segment those bands for national uses, the material is appropriate for discussion as a sharing method.

2.1.3 Frequency agile systems

Frequency agile systems select frequencies of operation anywhere within a specified band on a real-time basis, using the techniques of listening before transmitting. These are systems that do not rely on a mutual coordination process or on another systems operator's decision. Frequency agile systems seek out unused spectrum for a communication. These types of systems may not be suitable for public telecommunications or for transfer of critical data because of a higher possibility for interference.

Technology has made some types of frequency agile radio systems quite feasible and relatively inexpensive today. If a system can tolerate the time necessary to often change frequencies and synchronize terminals, the technique can prove cost effective.

2.1.4 Dynamic sharing

Using advanced computer techniques, spectrum managers have greater opportunities to share frequencies, and thus greater opportunities to reduce inefficiencies created by rigid service boundaries. Dynamic sharing of frequencies between different systems in the same similar services allows more than one system to use the same frequencies but at different times, in the same geographic region. Traditionally, sharing the same frequencies at similar, high power in the same geographic area required adoption of discrete time periods for use by each service. Dynamic sharing techniques permit such sharing on an as-needed basis. Dynamic sharing requires reliance on sophisticated technologies and methodologies.

Trunking is an example of dynamic sharing. In a trunked system, channels that might otherwise be assigned to individual users are joined in a single system, and frequencies are automatically assigned to individual users on an as-needed basis. Trunked systems allow disparate users to share spectrum, and generally provide a significant increase in efficiency over conventional assignment methods.

Another type of dynamic sharing occurs between cellular providers and other users in the 900 MHz band. Access to these frequencies has greatly expanded the pool of available channels for cellular use. In this arrangement, the priority users have pre-emptive access to these frequencies, and as they

need them, computer software programs automatically reclaim the frequencies for the priority use, excluding them from cellular access. In such instances, cellular users would experience graceful degradation, rather than a complete loss of service.

Dynamic sharing is a possible means to improve efficiency in radio spectrum use in cases where it is feasible to merge services, and thus broaden radio service definitions. The effect of such sharing would be similar to reducing distinctions among subclasses of users. For example, in the 2 GHz band, mobile-satellite services (MSSs) were divided into three radio services: aeronautical, maritime and land-mobile satellite. At WRC-97 they were combined into a generic MSS. While the services are different, they have common aspects that could allow a sharing of the services under a broader classification, MSSs.

2.1.4.1 Dynamic real-time frequency assignment

The system now proposed for sharing among the MSSs is quite complex. It would involve a process of dynamic allocation, where each of the MSSs would be allocated spectrum on an as-needed basis, requiring a mechanism to implement priority and pre-emptive access, as necessary. Such systems serve a variety of users with diverse needs, including different and continuously changing requirements for channel bandwidth, signal power, priorities and network interfaces. The replacement of analogue with digital transmission technology may increase the potential for dynamic sharing.

2.1.5 FDMA

The FDMA technique consists of assigning to each user a fraction of the bandwidth and confining its access to the allocated sub-band. Orthogonality is achieved in the frequency domain.

2.1.6 Control of emission spectrum characteristics

The control of emission spectrum characteristics increases the amount of spectrum available to radiocommunications by limiting the amount of spectrum wasted to unwanted emissions (both spurious and out-of-band emissions). Sharing of spectrum is facilitated by increasing the efficient use of the spectrum. Control of unwanted emissions generally comes at a cost since methods such as filtering must be employed in system design to control these characteristics. Spectrum shaping through changing the RF and/or IF, baseband filtering to the transmitter or receiver transmission line, are the ways to improve spectrum efficiency by minimizing either transmitted energy or received voltage that are not necessary to recover desired information. Vestigial sideband filters on television transmission lines is one example.

2.1.7 Dynamic variable partitioning

Another sharing method which results in a flexible use of the spectrum is dynamic variable partitioning, which is real-time sharing of a block of spectrum among two services for which one service has priority over the other. In dynamic variable partitioning there is a partition that divides the channels contained in a block of spectrum into two portions, one for service A and the other for service B. The partition moves in real time in response to actual or perceived demand from service A. A network operation centre is required to respond immediately to provide the channels necessary for service A. The method is based upon the establishment of a buffer of channels to respond immediately to requests. This method of sharing has been simulated using a Monte Carlo simulation but has not, as yet, been validated operationally.

2.1.8 Frequency tolerance limitation

Frequency tolerance is defined as the maximum permissible departure by the centre frequency of the frequency band occupied by an emission from the assigned frequency or by the characteristic frequency of an emission from the reference frequency. The limitation of frequency tolerance cuts down the wasting of spectrum by controlling the wandering in frequency of the transmission signal increasing the number of systems that can operate within a portion of the spectrum.

At the same time, for the frequency converter purpose the frequency tolerance of the transmitter and receiver oscillators should also be limited to avoid the degradation of system performance and increased interference.

2.1.9 DAMA

The main disadvantage for pre-fixed assignment of channels is that it is hard to match the traffic random variation. For the thin route case with little traffic for every station, where the network or system has a great number of stations, using DAMA technology is most suitable for increasing spectrum efficiency; DAMA single channel per carrier (SCPC) system and single channel per carrier, pulse code modulation (PCM) multiple access, demand assignment equipment (SPADE) system are the typical examples of this type of application.

2.1.10 Frequency diversity

When radio propagation fading varies with frequency and the fading at different frequency location has a different level with small or negligible correlation, using the frequency diversity would obtain quite obvious diversity gain combined with the channel hitless (error-free) switching. The frequency diversity gain depends on the fading dispersion characteristics and the correlation factor between the frequency locations for diversity, as well as the performance of hitless (error-free) switching.

2.2 Spatial separation

2.2.1 Geographical shared allocations

Users in different geographical areas can reuse the same frequency if separated by sufficiently large distances. Geographical or area sharing of frequencies is a technique that speaks for itself and has long been considered of practical application. This type of sharing has been used for many years on a global basis in the HF broadcast band, for example. It is useful in any band depending on the requirement for service links and geographical coverage. It can take into account the characteristics of propagation to facilitate its use. This is also a technique that can use, to advantage, specific antenna system characteristics. In space service bands, where antennas point to the GSO, and depending on the latitude of operation which in turn determines the elevation angle and boresight direction in three dimensions, it may be possible to share spectrum around a terrestrial terminal. Antenna diversity and antenna pattern shaping can be an aid to geographic sharing either through automatic or manual switching between sites.

Another possible sharing method is to allocate a block of spectrum to two or more services and then implement the sharing within administrations by geographically separating users in the different allocated services. This utilizes sharing by separation in the spatial coordinate of spectrum. An
