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Rohde & Schwarz GmbH & Co. KG*

MANAGING AND MONITORING THE RADIO-FREQUENCY SPECTRUM

RADIO MONITORING AND FREQUENCY MANAGEMENT SYSTEM

A future-oriented and paying investment

Bernhard EARNST

As we all well know from the media, we are moving more and more towards becoming an information society. Modern life, and economy in particular, depends critically on its communication infrastructure of which radiocommunication is a key component.

Radiocommunication is essential for future creation of wealth, competitiveness and employment.

1 The radio spectrum - a limited resource

1.1 The radio spectrum is usually taken to comprise that part of the electromagnetic spectrum between frequencies of 3 kHz and 3 000 GHz. With present technology, it is not yet practical to use spectrum much above 100 GHz. Different frequencies have different characteristics making them suited for particular applications. Broadly speaking, lower frequencies travel further and so are useful for applications such as broadcasting. Higher frequencies travel less far which limits their usefulness in some respects, but means that they can be re-used more intensively and have greater information carrying capacity. Technical developments are continually raising the upper limit of the useful spectrum and developing ways of using lower frequencies more intensively. The problem is greatest in the range from 30 MHz to 30 GHz. These are currently the most useful frequencies and most frequently in demand. It is in that part of the spectrum that problems of actual or incipient congestion are worst. The problems are greatest in and between major cities where radio traffic is most intense.

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1.2 The spectrum is used for radio and television broadcasting, and the microwave and satellite links which carry long distance telephone calls, facsimiles, telexes and data communications.

It is also used by mobile radio, cellular service and paging companies. Commercial airlines, taxi and trucking companies, towing companies, couriers and delivery agents, construction companies and building contractors, oil exploration and utility companies, farmers and retailers also depend on the effective management of the spectrum for operating private communications systems.

Governments and agencies also use the spectrum for armed forces, police, ambulance air traffic control, marine safety, emergency and public safety services.

Ambulance paramedics use the spectrum to transmit vital patient cardiac information while on route to hospital, allowing diagnosis to begin before arrival.

Police officers use radiocommunications to coordinate their movements and consult central police computers from their vehicles.

Radio signals in the form of radar are used by air traffic controllers to establish aircraft positions and prevent collisions, and in aircraft instrument landing systems, guiding pilots to safe landings at night or in case of poor visibility.

Shipboard radar and radiocommunication systems play a vital role in marine navigation, particularly in bad weather and in communication with shore-based stations. Radio signals from ships and aircraft can provide vital communication for search and rescue.

The use of spectrum-related technology is becoming more prevalent in the work environment with the use of wireless networks linking several computers in the same building, city, or across countries.

In our homes, spectrum is being used increasingly, not only for receiving radio and television broadcasts, but to operate alarm systems, cordless telephones, remote controls, microwave ovens, and garage door openers.

1.3 Increasing demands

Economic growth, the introduction of competition, and choice in telecommunications, broadcasting and technical innovation have fuelled a seemingly insatiable demand for spectrum. Annual growth ranges from a steady 5% for private business radio through 30% for trunked public access mobile radio to 60% for cellular telephony. The pressure on the available spectrum is rising and increasingly difficult to accommodate.

As an example, the use of GSM cellular communication is growing drastically.

Today, five countries in the Middle East: Lebanon, Kuwait, Saudi Arabia, the United Arab Emirates, and Qatar account for more than 300 000 GSM subscribers. The growth of European digital subscribers is shown in the table below.

Worldwide, there were over 16 million GSM subscribers by the end of March 1996. This number is increasing at a rate of over one million per month.

1.4 The radio spectrum as a resource

The radio spectrum is a natural resource which cannot be enlarged. Being part of our environment it has to be maintained to provide the most effective use for communication. The major factors which determine the quality of the spectrum are:

– interferences of licensed users (nationally and internationally);

– man-made interferences;

– interferences of unlicensed users.

To keep the quality of the spectrum, it is necessary to detect and avoid those interferences technically and by means of administrative measures.

ITU set the relevant rules and recommendations for spectrum management and radio monitoring.

These rules and recommendations allow the governmental authorities to do both:

– to serve their clients best; and

– to secure the license revenues.

2 Spectrum management and radio monitoring

As stated above, the radio spectrum has to be managed and planned carefully. This is not only a national task. Radio waves do not respect national borders. Necessary international coordination and management is carried out by ITU.

2.1 Spectrum management - definition

Spectrum management is the combination of administrative, scientific and technical procedures necessary to ensure the efficient operation of radiocommunication equipment and services without causing harmful interference. Simply stated, spectrum management is the overall process of regulating and administering use of the radio-frequency spectrum. The goal of spectrum management is to maximize spectrum efficiency and to minimize interference. Rules and regulations, based on relevant legislation, form a regulatory and legal basis for the spectrum management process. Databases of information, including details of all authorized users of the spectrum, provide the administrative and technical basis for the process. Analysis of the information in these databases facilitates the spectrum management process resulting in decisions for spectrum allocations, frequency assignments, and licensing. Spectrum monitoring provides the inspection, verification and enforcement necessary to maintain the integrity of the spectrum management process.

The diagram shows the basic elements of a spectrum management system.

There are three major groups of tasks:

– spectrum allocation for a particular type of use, such as, for example, air traffic control, cordless telephone or microwave links, etc.;

– frequency coordination which permits the optimum use of the allocated spectrum by a maximum number of users;

– licensing, spectrum pricing, billing, enforcement. A powerful database has to be established to carry out these administrative tasks.

The effectiveness of this part of spectrum management is decisive whether or not the entire process of the spectrum management will be profitable for the respective authority.

In particular, a spectrum pricing policy has to be established which has to be oriented either on a cost-return basis or on the spectrum market situation.

The benefits of the spectrum management cannot be realized without effective enforcement procedures to make sure that the users comply with their licenses and the technical rules and regulations.

– Radio-spectrum monitoring

  Radio monitoring is closely related to the spectrum management as it provides reliable data for both planning and verification of the spectrum.

2.2 Radio monitoring systems

Radio monitoring data are a prerequisite for spectrum management.

At the highest level, the data required are:

– data concerning actual spectrum occupancy versus authorized occupancy;
– deviations from authorized transmission parameters;
– data regarding the location and transmission parameters of legal and illegal emitters;
– data regarding interference between or among transmitters; and
– recommendations to resolve interference.

Operators also need these data as well as parametric data regarding signal centre frequency, bandwidth, power, modulation type and rate, azimuth direction or location of signal source, the time signals are present, emitter identification and signal content.

These data may be grouped as follows:

1) identity and location of illegal/unknown/unauthorized emissions;
2) bands/frequencies experiencing congestion, interference and/or coordination problems;
3) spectrum occupancy capacity;
4) measurement of authorized emitter parameters to include power, frequency, bandwidth, modulation type and rates.

Unlike the spectrum management system, which basically consists of a computer system and the relevant software, the radio monitoring system requires significant hardware investment.

The following diagrams and pictures show the basic architecture of a nationwide radio monitoring system and examples of realized installation, both stationary and mobile ones.

The complexity of such a radio monitoring system varies widely depending on:

– the size and topography;
– the number and distribution of the population;
– the number of radio services established;
– the economic situation,

of the respective country.

Related to these parameters, it is certainly possible to build up the radio monitoring capabilities in subsequent phases. This means to start with a few stationary or mobile stand-alone subsystems and to network them later.

Further, the radio monitoring system has to provide enough growth potential - technically and operationally - to keep pace with the rapid development of radio monitoring technology.

3 Financial aspects of frequency management

Besides all the technical and operational aspects, frequency management can be "profitable" for the authority.

3.1 Economic benefits of frequency management

– High spectrum quality

The consequent application of frequency management and radio monitoring enables the authority to provide the radio spectrum as a high-quality product. This means, more clients can use the spectrum more effectively. This finally leads to more licences to be granted and higher fee revenues.

– Low number of unlicensed users

By using the capabilities of a modern radio monitoring system the number of unlicensed operating stations can be significantly reduced. In Germany, for instance, the estimated number of such stations is less than 1%. Again, radio monitoring and proper frequency management will lead to higher fee revenues.

– Impact on national economy

Studies have been made to figure out the impact radiocommunication has on national economy. According to a British study (1995/96), to give an example, the economic contribution of radio is as follows:

- **on wealth creation**: over $US 15 billion a year at 1994 prices, amounting to 1.5% of UK gross domestic product when manufacturing, retail and service activity associated with radio are all taken into account;
- **on competitiveness**: $US 10 to 17 billion of efficiency gains and consumer benefits;
- **on employment**: over 300 000 jobs.

3.2 Costs of frequency management

Basically, the costs of frequency management differ significantly in different countries. They highly depend on the level of frequency management.

To give an example: the entire costs of frequency management including operation administration, licensing, billing, radio monitoring and the relevant investment yielded an amount of $US 140 million in the Federal Republic of Germany in 1995/97.

This amount is split into:

– 60% (= $US 84 million) for personnel costs; and

– 40% (= $US 56 million) for non-personnel costs.

For capital investment 10% (= $US 14 million) of the total amount is spent.

These figures are certainly comparable to those of other member states of the European Union, but may differ in non-EU states.

3.3 Scenario example for investment in frequency management

This example will show how investment for establishing a frequency management and radio monitoring system can be profitable for an authority, even if financial factors are considered only.

The capital investment should be $US 1 million. The time period considered is ten years.

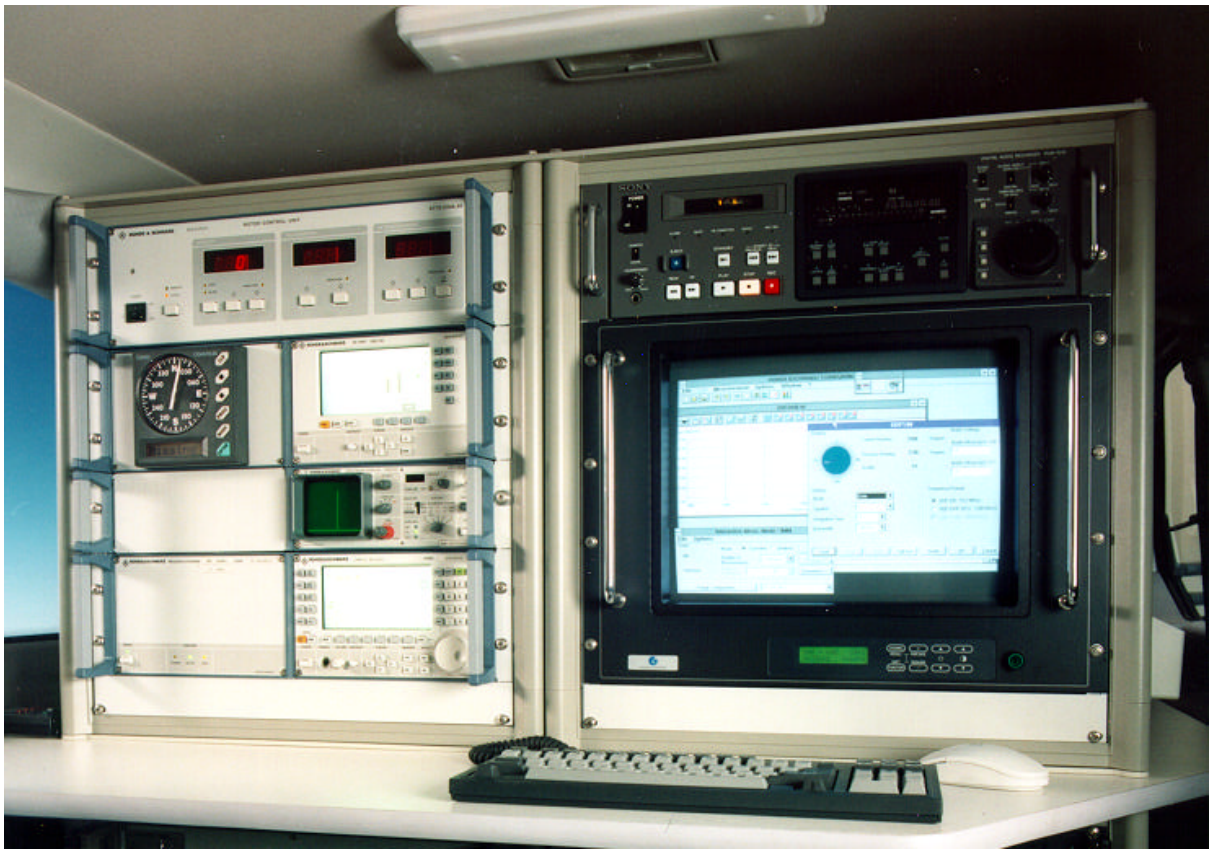
An increase of the licensing fees of 5% per annum and of the collection rate from 50% to 100% by the end of the period is assumed due to the system effectiveness.

Tables 1 to 3 show the profit loss calculation, the capital expenditure and the cash flow development of the investment example.

The cash flow development, in particular, demonstrates that establishing a spectrum management system is a profitable investment.

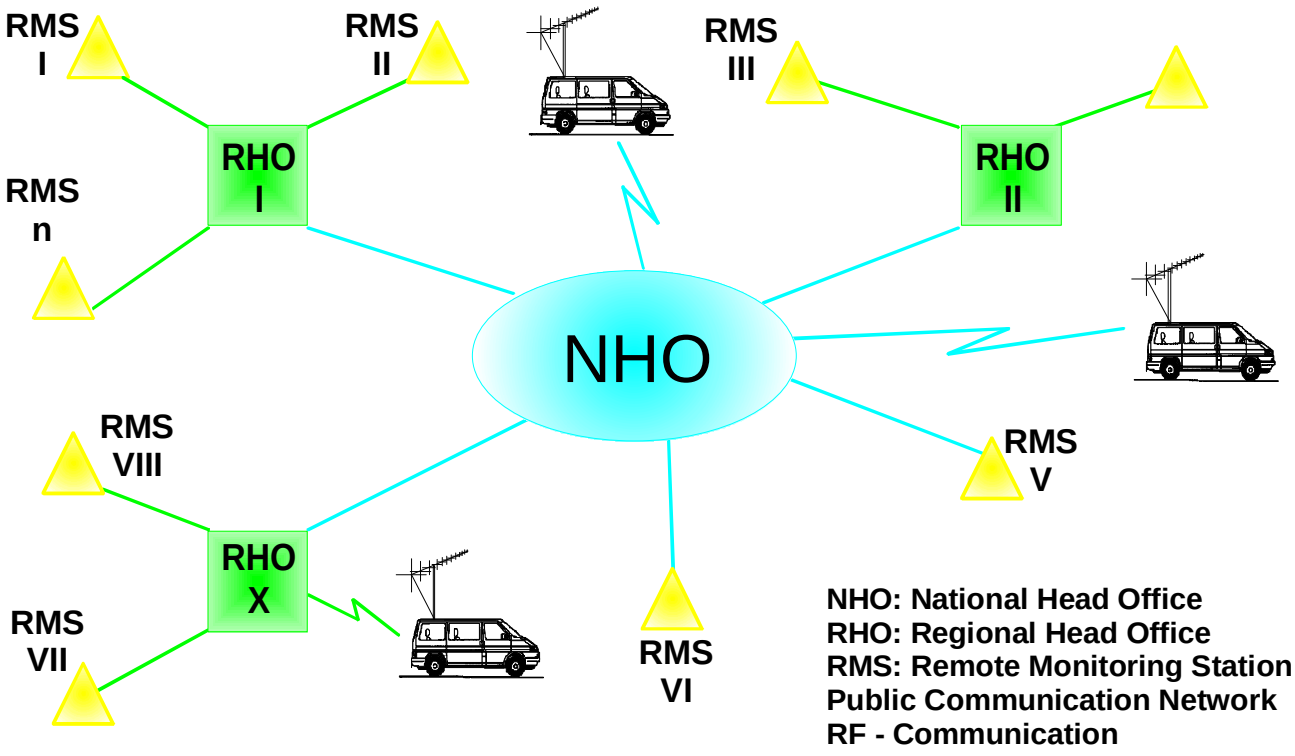
ARGUS mobile system

ARGUS fixed station



Rack of a mobile DF vehicle

Operator position



System networking

	Profit & Loss in USD '000'							
		1997	**1998**	**1999**	**2000**	**2001**	**2002**	
	Revenues	350	490	643	810	851	893	9
	potential revenues	*700*	*735*	*772*	*810*	*851*	*893*	
	collection rate	*50 %*	*67 %*	*83 %*	*100 %*	*100 %*	*100 %*	
-	Operating and admin. expenses	250	265	281	298	316	335	3
-	Depreciation	0	100	110	120	130	140	1
	Operating Profit	100	125	252	393	405	419	4
-	Interest on Debt	0	120	108	96	84	72	(
=	Pre-Tax Income	100	5	144	297	321	347	3

12%	cost of capital	
100 000 US$	per annum loan repayment for the initial debt	
50 %	collection crate for frequency licences in 1997	
100%	collection rate for frequency licences in 2000 and beyond	
5%	per annum increase in licencing fees	
6%	per annum increase in operating expenses	

	Profit & Loss in USD '000' (without frequency management unit)							
		1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2**
	Revenues	350	356	363	370	377	384	3
-	Operating and admin. expenses	200	212	225	238	252	267	2
=	**Operating Profit**	150	144	138	132	125	117	1
=	Pre-Tax Income							

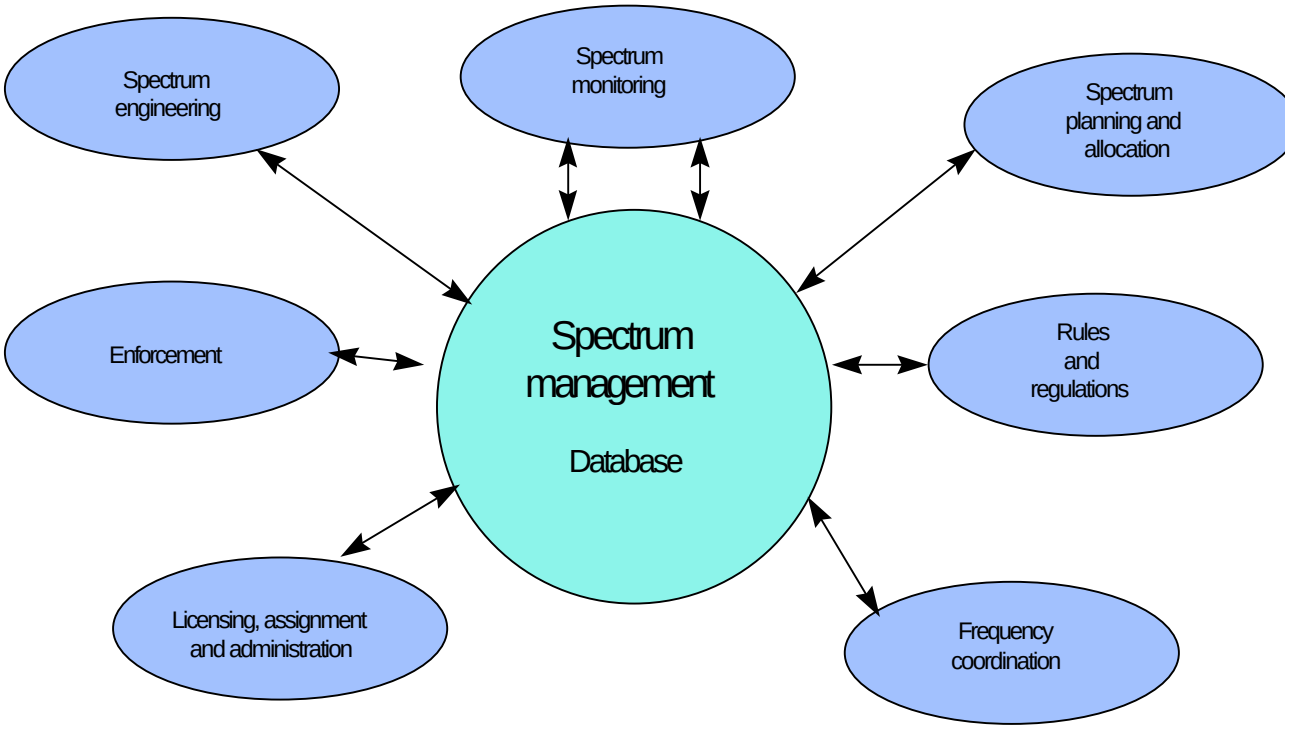
50 %	collection rate for frequency licences in 1997	
3 %	decrease in collection rate per annum (new users will try not to pay as they see	

	Cash Flow in USD '000'	1997	1998	1999	2000	2001	20
	Cash In						
	Cash from operation (profit & loss)	100	105	254	417	451	
	Loan	1000	0	0	0	0	
	Cash Out						
	Capital expenditures	1000	100	100	100	100	
	Loan repayments	0	100	100	100	100	
	Free Cash Flow (FCF)	100	-95	54	217	251	
	Cumulative free cash flow	100	5	59	276	527	
	discounted FCF	100	-85	43	154	160	
	Cumulative discounted FCF (cost of capital = 12%)	100	15	58	213	372	

net present value (NPV) for the period until 2006 = 1.182.000 US$ (further increase after 2006)

	Cash Flow in USD '000' (without frequency management unit)						
		1997	**1998**	**1999**	**2000**	**2001**	
	Cash In						
	Cash from operations (profit & loss)	150	144	138	132	125	
	Cash out	0	0	0	0	0	
	Free Cash Flow (FCF)	150	144	138	123	125	
	Cumulative free cash flow	150	294	432	564	689	
	Discounted FCF	150	128	110	94	79	
	Cumulative discounted FCF (cost of capital = 12%)	150	278	388	482	561	

net present value (NPV) for the period until 2006 = 787.000 US$ (further decrease afte



Basic elements of spectrum management