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SOME TESTS OF SPECTRUM USAGE IN BRUSSELS, BELGIUM

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I. OVERVIEW OF THE TEST

This chapter is a small excerpt from the author's PhD Dissertation, which contains twenty chapters and totals more than 650 pages.[1] The purpose of this chapter (here, it is a short article, but it will nonetheless be referred to as a chapter) is to share some data that was used to support the Dissertation's larger hypothesis that the most valuable spectrum (below 3 GHz) is misallocated and poorly used. Legal and policy arguments extracted from other chapters of the Dissertation have already been (or are in the process of being) published separately[2] in the hopes that this information may prove valuable to others.

Most dissertations in the law faculty involve analysis of legal doctrine and policy. This traditional approach is useful and appropriate for almost all legal disciplines where scientific and empirical investigation can be segregated from legal analysis, as is the case with issues related to constitutional law or tort law. Why, then, did we conduct an empirical test? Simply put, in matters involving wireless spectrum management, science and law are forever intertwined. Regrettably, in this domain engineers often misunderstand or ignore matters of law and policy; likewise (and more importantly), lawyers often understand little about science. In spite of the natural symbiotic relationship between science and law that exists in this wireless arena, the two disciplines rarely seem to join forces.

This chapter will help to bridge this unfortunate gap by offering an empirical, scientific examination of spectrum usage in a major metropolitan area. The pragmatic and relevant data resulting from the innovative approach taken here will help to illuminate some of the critical issues involved in this significant area of study. Nonetheless, this test, the applied testing methodology, and the resulting data together constitute only a preliminary step in the research process. Thus, the author hopes that future studies of a similar nature are conducted in major metropolitan centers worldwide. The analysis itself was made possible because of a cooperative study between the Faculty of Law and the Faculty of Engineering. A full analysis of the engineering test and of the data obtained as a result of that test is attached in the Annex. In this chapter, we shall consider certain aspects of the test data that are not covered in the Annex.

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[1] Patrick S. Ryan, "The Effect of Emerging Wireless Technologies on the Law and Regulation of Wireless Spectrum Allocation in the United States and the European Union," Ph.D. Dissertation, Faculty of Law, Katholieke Universiteit Leuven (dissertation defended and degree awarded on July 11, 2004). A copy of the Dissertation is available in the KU Leuven law library.

[2] *See* Patrick S. Ryan, *Application of the Public-Trust Doctrine and Principles of Natural Resource Management to Electromagnetic Spectrum*, 10 MICH. TELECOMM. AND TECH. LAW REV 285 (2004), *available at* http://ssrn.com/abstract=556673; *War, Peace, or Stalemate: Wargames, Wardialing, Wardriving, and the Emerging Market for Hacker Ethics*, 9 VA. J. OF LAW & TECH. 7 (2004), *available at* http://ssrn.com/abstract=585867 [hereinafter: Ryan, Wardriving]; *Wireless Communications and Computing at a Crossroads: New Paradigms and Their Impact on Theories Governing the Public's Right to Spectrum Access*, J. ON TELECOMM. AND HIGH TECH. LAW, Forthcoming 2004. This latter piece (and future work) will be made available on the Social Science Research Network on my author page, *available at* http://www.ssrn.com/author=355448.

A. The Test

First, we shall provide an overview of the test that we conducted, including details regarding the manner of its supervision, the data that were measured, and the reasons underlying the selection of various testing parameters. In addition, we will address some potential weaknesses in the test.

1. Supervision of the Test

The test was conducted and supervised by Professor Emmanuel Van Lil and Jan Potemans, both of the Electrical Engineering Department of Katholieke Universiteit Leuven.[3] Professor Van Lil and Mr. Potemans work in the Telecommunications and Microwaves (TELEMIC) department, which regularly conducts and evaluates studies of radio frequencies.

2. Frequency Range

The purpose of the test was to analyze the usage of frequencies from 30 MHz to 6,200 MHz (*i.e.*, 6.2 GHz) in a major metropolitan area. This frequency range was chosen for the following two reasons:

1. These frequencies cover the spectrum with the highest value, also known as the "beachfront property."[4] Frequencies within this range have the capability to penetrate obstacles, thus making them appropriate for mobile applications.[5]

2. These frequencies also are those which have the greatest day-to-day impact on our lives. Most common wireless devices operate within this range, including, *inter alia*, Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) phones, wireless fidelity (Wi-Fi) equipment, AM and FM radio, broadcast television, aeronautical communication technologies, and radio navigation tools.

3. Location

We chose to conduct the test in the downtown area of Brussels, the capital of Belgium. The city was chosen because it is a representative major European

[3] The author is grateful for the financial support of Professor Dumortier and the Interdisciplinary Centre for Law and Information Technology for making this analysis possible.

[4] The lower frequency ranges are often referred to as "beachfront property" because they are the most desirable—and the most expensive—of all of the frequencies. In addition, the public trust doctrine has protected the public's right to "beachfront" access.

[5] The frequencies from 30 MHz to 3,000 MHz have the best ability to penetrate obstacles. The frequencies in the range of 3,000 MHz to 5,000 MHz can also penetrate obstacles, though they have greater attenuation. Frequencies above 5,000 MHz are generally considered to have line-of-sight uses.

metropolis. While it is not the largest city in Europe, its population of 1,000,000 puts it in the top tier. Further, it is the *de facto* political capital of the European Union, since Brussels is the home of the European Commission, the home of the European Council, and the second home of the European Parliament, as well as the headquarters for NATO. Finally, more multinational corporations are based in Brussels than in any other European city,[6] and the city attracts more than 1,000 business conferences annually.[7] Taking all of this data into consideration, we believe that the city location provides an excellent point of reference for assessing frequency usage in urban centers located in Europe and quite possibly throughout the world.

The test was conducted from the ASTRID building,[8] which is a centrally located seven-story building at a high point near the city center.[9] We placed antennas on the roof of the building and routed the signals via a pre-existing 36 meter antenna cable from the roof to the communications center on the sixth floor.[10] This configuration gave us ideal access to the roof, while at the same time allowing us to protect the equipment by housing it indoors. From this location, we were able to pick up the kinds of signals generally found in an urban setting. The most likely signals came from nearby GSM "base stations." Because of the low power of handsets, it is unlikely that we sensed much activity from pedestrian traffic on Wetstraat, Avenue Louise, and other key areas of downtown Brussels (this general location is the home of many national ministerial buildings and European Community buildings).

4. Timing and Duration of the Test

As is the case in many cities, especially those that serve as international centers of political activity, commuters stream into Brussels each weekday. Thus, we decided to conduct our test on weekdays in order to obtain data during peak periods of mobile-application use. In order to accommodate the full frequency range through 6,200 MHz, we used three separate antennas. Accordingly, we conducted three separate tests that lasted twenty-four hours each, thus allowing us to investigate variations in frequency use during the day (*i.e.,* during business hours) and during the night. Data was captured in five-minute intervals, with samples each lasting roughly one second. The schedule was as follows:

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6 *Id.*

7 Brussels is the home of more than 2,000 multinational headquarters and more than 60 international bank branches. *Brussels: Facts and Figures*, THE ECONOMIST, *available at* www.economist.com (subscription req'd) (last visited March 4, 2004).

8 ASTRID is the security communications office of the Belgian authorities. ASTRID stands for All-round Semi-cellular Trunking Radiocommunication network with Integrated Dispatchings. *See* http://www.astrid.be.

9 The author of the Dissertation reiterates his gratitude on behalf of ICRI to Mr. Kristof De Pape and Mr. Olivier Anizet for granting permission to Professor Van Lil's team to conduct this investigation.

10 Please see the Annex for details on the cable length and on the calculations for signal loss associated with the cable.

- The first test was conducted from 11:20 am on Tuesday, February 24, 2004, to 11:20 am on Wednesday, February 25, 2004. This test sampled the **30 MHz to 200 MHz** frequency range.

- The second test was conducted from 12:05 on Wednesday, February 25, 2004, to 13:25 (1:25 pm) on Thursday, February 26, 2004. This test sampled the **200 MHz to 1,000 MHz** frequency range.

- The third test was conducted from 14:04 (2:04 pm) on Thursday, February 26, 2004, to 14:20 (2:20 pm) on Friday, February 27, 2004. This test sampled the **1,000 MHz to 6,200 MHz** frequency range.

B. Potential Estimation Errors

Because of timing and budget constraints, we limited our test to the above-mentioned criteria. Accordingly, a number of alternate scenarios could have been implemented. For example, we could have tested each frequency range for longer periods of time (*e.g.*, one week), or we could have used more expensive equipment to test frequencies at higher resolution[11]. However, since the purpose of our test was to collect data that would provide a general empirical overview of spectrum usage, we adopted the testing methodology described herein. Furthermore, some of the limitations associated with the test parameters selected may cause overvaluation or undervaluation of available spectrum amounts. Some variations in the accuracy of data derived from experimentation are common in scientific analyses. Nonetheless, it is important to note that these testing constraints may have some effect on the precision of the data gathered, as described below.

1. Possible Underestimation of Available Spectrum

Many factors could lead to an underestimation of available (*i.e.*, unused) spectrum, including the following:

- POSITIONING OF THE ANTENNAS. We made an effort to aim the antennas in such a way as to receive the highest possible signal response on the spectrum analyzer. Thus, our intention was to capture data showing the highest frequency use during the designated test period. However, this alignment was done in accordance with frequency use at a given time of day, and it is

[11] For example, the resolution could be increased in two ways: (1) measure more frequency points (*e.g.*, instead of taking one measurement each MHz, measure each 100 kHz), which could have allowed us to pinpoint different GSM channels, etc.; (2) take more measurements per time unit (*e.g.*, instead of taking one measurement per five minutes, we could have taken one measurement every five seconds). Increasing the resolution, however, is a more time-consuming and expensive endeavor, and it is questionable whether we would have had an outcome of any statistical significance.

possible that our testing antennas might have been oriented in a different manner at other times during the day.

- LOCATION OF THE TEST. While the test location (downtown Brussels) provides an opportunity to acquire excellent data regarding spectrum usage in a large metropolitan area, data captured at that location is not representative of data that would be captured in other areas in Belgium or in non-urban areas in general. If the same test had been conducted in a rural area in Flanders or Wallonia, for example, the results undoubtedly would have reflected a greater amount of unused spectrum than the amount used in Brussels.

- DURATION OF THE TEST. Since our three separate tests lasted only twenty-four hours each, it is possible that certain frequencies were used during this test period that may not often be used.

2. Possible Overestimation of Available Spectrum

Likewise, a number of factors could lead to an overestimation of available spectrum:

- AERONAUTICAL AND MARITIME TRAFFIC. Our test was conducted a few kilometers away from the Brussels airport; as such, we probably did not record many of the communications that took place between aircraft and airport authorities (although we clearly did record some activity). In addition, Brussels is not near a port, so we were unable to record maritime traffic.

- LOW-POWER USES. Recognizing that hundreds of Wi-Fi hotspots are located in Brussels, we attempted to capture data regarding the use of Wi-Fi networks operating in the 2.4 GHz range. However, we were unable to record any such usage. Thus, low-power applications like Wi-Fi (and possibly other low-frequency applications as well) fell below our testing threshold.

- POSSIBLE SAMPLING ERRORS. Our testing interval (one second every five minutes) tended to capture data on spectrum used on a regular basis. Accordingly, it is possible that some applications evaded our test intervals and subsequently were not reflected in our data.

In spite of these possible overestimation and underestimation errors, we believe that this test provides a reasonable (and worthwhile) approximation of spectrum use within the 30 MHz to 6,200 MHz range. We would encourage others (*e.g.*, governments, academics, and private organizations) to conduct similar tests in order to obtain data with an even higher degree of accuracy.

C. Analysis of Results

It would be impractical to analyze the results of all of the uses of the spectrum within a given range. For this reason, a few broad spectrum ranges will be selected and discussed. As previously mentioned, a full list of frequency allocations is included in the Annex, which also provides further details on other active and inactive portions of the spectrum.

II. LOWER BANDS: 30 MHZ TO 200 MHZ

A. Overview

Our first set of measurements considered the lower band of radio frequencies from 30 MHz to 200 MHz. Data was captured using a specialized biconical,[12] omnidirectional[13] antenna (refer to the Annex for antenna specifications and technical details).

The lower frequencies were the first to be used by pioneers in wireless technology and thus were the first frequencies for which applications (*e.g.*, maritime applications and FM radio) were developed. It is within this lower band that frequencies have the longest range and the highest capability to penetrate obstacles. It should come as little surprise, then, that these lower bands were among the most occupied (*i.e.*, used) of all of the bands that we tested.

In this section, we will review two bands in detail: (1) FM radio (87.5 MHz to 108 MHz), which has been officially allocated to "FM sound analogue,"[14] and (2) frequencies ranging roughly from 140 MHz to 180 MHz, which have been allocated for miscellaneous uses, including space operations, aeronautical communications, weather satellites, and maritime communications.[15] In reviewing the various uses of these frequencies, we have reached the following conclusions:

- In spite of the fact that the FM band appears to be very full—in fact, it is perhaps the most highly used frequency band that we tested—we have continued to find new ways to take advantage of these frequencies. Within this context, we will provide a short case study that examines products that apply the FM subcarrier principle, as described below.

- The second frequency range showed much less activity than did the FM band. However, in spite of the fact that these frequencies

[12] A biconical antenna has two conical conductors, extending in opposite directions, with a common axis and vertex.

[13] An omnidirectional antenna can receive signals from a 360 degree radius.

[14] *See* the BIPT regulations, incorporated by reference in the Annex.

[15] The applications authorized within this range are far too many to enumerate. *See* the BIPT regulations, incorporated by reference in the Annex.

are not always occupied, they are used for critical public-safety operations and meteorological services. Because of the public benefits derived from the current allocation of these frequencies, it is probably best that the allocation remains unchanged for the present. Nonetheless, we should continue to encourage these frequencies to be used for cognitive digital devices rather than for inefficient analog devices, and we should set an outside timeframe by which these frequency bands should be made available to others for more open use. This Dissertation suggests that these frequencies undergo a twenty-year migration period.

B. FM Band Analysis and Case Study

Figure 1 shows the first set of measurements, which considered the lower band of radio frequencies from 30 MHz to 200 MHz. From looking at this graph, it would appear that the FM band is not available for additional use. Not only does the band appear to be fully occupied along the x-axis (which shows the frequencies allocated to this band), but also, as can be seen by looking at the y-axis, the intensity of the use of these frequencies (the power levels) is the highest of any other frequency band that we measured.[16] Furthermore, the minimum, average, and maximum test levels were almost identical throughout the FM band, indicating that the FM signals were, without question, one of the most widely (and continuously) used bands that we measured. These test results might lead to the logical conclusion that this band is full and that other uses within this band are not possible. After all, FM radio is one of the most successful and most extensively used areas of the radio spectrum. Millions of people depend on these frequencies for news, traffic and weather information, emergency information, and even music and entertainment.

However, in spite of the appearance that the band is full, the band can be used in a number of new ways. In fact, as we will see shortly, many additional uses have been added to the FM band within the past couple decades with no degradation of FM service. The lessons learned from this example are important, for presumably they can be applied not only to the FM band—a band that continues to use outmoded, inefficient, low-quality analog signals—but also to other bands and other parts of the spectrum that are less exploited than the FM band and that use more modern digital broadcast techniques.

[16] The y-axis indicates the electric field level in dBV/m. The power density in Watt/m² equals the field in V/m squared, divided by 377 Ohms. The relative difference in a dB graph between two values, however, is the same because one takes 10 log10 for the power density and 20 log10 for the field.

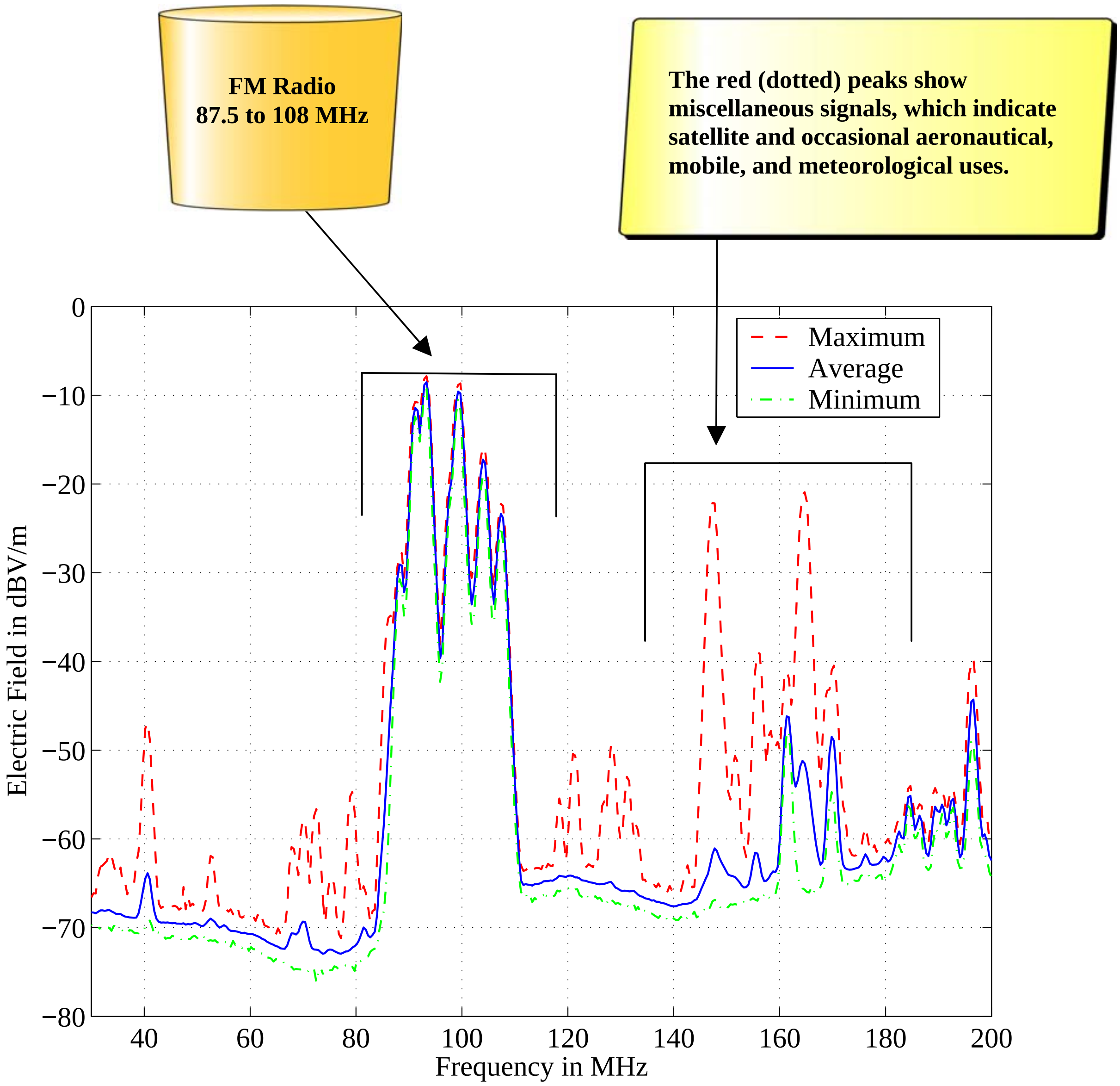

Figure 1 Graph showing the lower-band spectrum sample, 30 MHz to 200 MHz.

1. FM Radio Transmission Technology Remains Unchanged

FM radios are one of the longest-lasting technology devices in the world. They are much more durable than almost any other electronic or mechanical devices built over the past fifty years, including automobiles, washing machines, light bulbs, refrigerators, televisions, and tape and record players. The basic underlying transmission technology of FM radio has been frozen in time by regulators since its inception, and the functionality is virtually the same as it was back in the 1940s. Nowadays, the devices' window dressing has changed, and knobs and dials may have been replaced by digital displays. Nonetheless, an FM radio from 1960 will work just as well as one purchased in 2004.

One reason that the transmission technologies have remained stagnant is that changes or upgrades to those technologies would require everyone in the world to purchase a new radio.[17] To date, governments have been unwilling to stipulate the mass repurchase of radios worldwide for a couple of reasons. First, almost everyone owns a radio, and many people who live in rural areas depend upon radio broadcasts as a key source of information. Second, radios provide a critical means of disseminating information during national emergencies or terrorist attacks.[18] Although these arguments are convincing—mainly because they reinforce ideas related to consumer protection and public safety—this line of reasoning quickly loses traction upon further analysis. In fact, similar arguments have been used in other areas of policy to encourage us to do the exact opposite—to *improve* our technologies and to phase out older, less efficient products. Some examples are listed below:

- New building codes have required the complete rewiring and rebuilding of home electrical systems to replace old "knob and tube" wiring with safer systems.[19]

- Gas lamps have been outlawed, and electric light bulbs must now conform to strict standards.[20]

- Plugs on the ends of electronic devices have changed throughout Europe, thus requiring that consumers replace (or purchase adaptors for) many electronic devices manufactured within the past thirty years.

- Automobiles with two-stroke motors were replaced by automobiles with four-stroke motors, and leaded gas was replaced by unleaded

[17] One of the reasons that FM radio is so protected is for security reasons. U.S. Homeland Security Secretary Thomas Ridge has stated that "obviously television and radio … are the first choice" for disseminating information to the public during a terrorist attack. His belief is that battery-operated radios and televisions should be included in each home's emergency supplies. PBS Online News Hour, *Newsmaker: Tom Ridge*, February 19, 2003, *available at* http://www.pbs.org/newshour/bb/terrorism/jan-june03/ridge_2-19.htm (last visited January 17, 2004) (quoting Tom Ridge). *See also* U.S. Department of Homeland Security, "Make a Kit," *available at* http://www.ready.gov/supply_checklists.html (last visited January 17, 2004) (recommending that everyone keep a radio and a television in their home's safety kit).

[18] Recall, however, that FM transmission was in fact proven to be possible since the 1940s, and its inventor, Edwin Howard Armstrong, committed suicide after spending fifteen years trying to convince the Federal Communications Commission that it would work. *See* LAWRENCE LESSING, MAN OF HIGH FIDELITY: EDWIN HOWARD ARMSTRONG (Bantam Books: 1956).

[19] *See e.g.*, U.S. Department of Housing and Urban Development, Chapter 1, at 1-26 (regarding the upgrade of electrical and plumbing systems to newer technologies).

[20] *See New York Merchandise Co., Inc. v. U.S.* 1946 WL 4525 (1946) (describing the history of the light bulb, the growth of the industry, and the different classifications and standards for gas lamps, incandescent lights, and various fixtures).

gas, thus requiring different nozzles for the different types of gas tanks. Further, motors, carburetors, fuel-injection systems, and all motor components have changed over the years. In Europe, an automobile that is more than ten years old must receive special authorization on an annual basis (in Belgium it is four years) in order for it to be permitted to drive on the road.

- Rotary-dial telephones have been replaced by push-tone phones (many rotary phones will no longer work in some telephone systems).

- Black-and-white television sets have been replaced by color television sets.

- Telex machines have been replaced by fax machines.

- VCRs are now being replaced by DVD players.

- Phonographs and cassette tapes have been replaced by CDs.

- Dot-matrix computer printers have been replaced by ink-jet printers, which, in turn, are now being replaced by laser printers.

- Personal computers generally have a three- or four-year lifecycle and are often replaced at the end of that lifecycle.

The preceding list offers just a few examples of the ways in which older, outdated technologies have been replaced by modern technologies. In short, virtually every electronic and mechanical device that we use in our homes has been replaced by a newer, more efficient model. Every device, that is, except our radios. Therefore, it appears that analog technology is here to stay for the foreseeable future.[21]

In spite of this criticism, in many ways, it is perhaps unfair to attack the regulation of FM radio; after all, FM radio uses only a fairly limited portion of the spectrum, and complimentary digital radio products are in limited deployment. Nonetheless, the story of FM radio is an important one. Radio frequencies have been partially deregulated in the past twenty years, and in spite of the fact that the FM band seems full, we have still found ways to extrapolate even greater value from this small sliver of the spectrum. Through what is known as a "subcarrier," FM radio is now used to provide one-way transmissions for such services as weather warnings, station identification announcements, and displays that show the name of the song being played. These subcarrier services will be explained below.

[21] Terrestrial Digital Audio Broadcasting is known as T-DAB. *See* Status of T-DAB Implementation in Europe, *available at* http://www.ero.dk/23EBF214-488F-4AAF-95CA-C10F1593E201.W5Doc (last visited March 1, 2004).

2. The FM Subcarrier Principle

These new FM services are sent over a "subcarrier," which has existed since 1983 in the United States[22] and since about 1987 in Europe (where it is commonly known as the Radio Data System, or RDS).[23] Its principle is this: local government authorities continue to allocate bandwidth to radio stations, and radio stations then transmit their regular programs on their main channel, called a "main carrier." However, these programs do not need to use the entire bandwidth, so stations are able to split their bandwidth into both a main channel and "subsidiary" channels, called subcarriers. To date, only one-way communications from subcarriers are allowed. In other words, FM radio broadcasters can send information to other users, but users cannot respond on the same FM radio frequencies. This type of communication is often called "point to multipoint" (or, in plain English, "one to many").

Interestingly, these new services make use of the seemingly congested FM spectrum. Transmission over a subcarrier frequency thus enables radio stations to transmit voice and data over other parts of their signals, assuming that these signals do not interfere with their main channel transmissions (it is, therefore, in the stations' own interest to manage these transmissions). As might be expected, this early form of radio deregulation inspired quite a bit of interest among stations that wanted to provide new one-way services (including the aforementioned traffic and weather reports, stock reports, news headlines, sports scores, and other data).[24] Before they authorized transmissions over subcarriers, governments spent many years analyzing possible drawbacks to subcarrier use [the Federal Communications Commission (FCC), for example, spent forty years producing and reviewing several dozen studies and orders on the subject].[25] And, because the subcarrier transmissions use the low-power band, we are unable to distinguish them from the main signals shown in the

[22] http://www.fcc.gov/mb/audio/subcarriers/ (discussing the FM subcarrier principle in the United States).

[23] The Radio Data System (RDS) was developed as a European standard for the transmission of digital data using subcarrier modulation on broadcast FM radio stations. The system was initially conceived to provide services to broadcasters that would support a new generation of intelligent radio receivers. Some of these capabilities include the transmission of program type codes, alphanumeric program identification fields, traffic alert and music/speech flags, and alternate frequency tables. *See* Michael Falcone, *Radio That Shows Text Makes Inroads in U.S.*, INTERNATIONAL HERALD TRIBUNE, January 5, 2004 (describing the functionality and history of RDS in Europe and noting that it is moving to the United States).

[24] In Europe, the subcarrier is used to transmit the name of the transmitting station over the digital display of a radio. In some countries like Germany, the subcarrier is used for a service called "FM-FM," which allows two different languages to be transmitted by a single station. Also, some radios are outfitted with a special ability to be "overridden" by a subcarrier in order to inform people of traffic or emergency warnings.

[25] *See e.g.*, Memorandum Opinion and Order in Docket 82-536, 98 FCC Reports 2d 792, released May 2, 1984; 47 CFR Section 73.1201, 47 CFR Section 73.1208, and 47 CFR Section 73.1212. *See* 47 CFR Section 73.127(d) for AM stations and 47 CFR Section 73.295(d) for FM stations; KMLA Broadcasting Corp. and *Musicast, Inc. v. Twentieth Century Cigarette Vendors Corp.*, 264 F. Supp. 35 (D. California 1967); Commission Policy Statement, Docket 87-9, 3 FCC Record 6323, released October 28, 1988; Letter to Dr. Haghighi from Richard B. Engelman, Chief, Technical Standards Branch, OET (1993).

graph. The main problem with the use of subcarrier services is that they allow one-way (receive) transmissions only, and for this reason they have not been as successful as many had hoped. The world, it seems, is becoming increasingly accustomed to two-way communications.

3. Microsoft's Approach to Subcarrier Transmissions

Microsoft has found a way around this problem. In 2003, Microsoft launched a product called Smart Personal Object Technology (SPOT),[26] which uses the FM spectrum to receive digital data. Since governmental restrictions still do not let users send information back on the same frequencies used to receive information, Microsoft has developed an Internet portal that allows users to customize the data that they receive (each watch has a specific code so that it only displays information intended for it). The basic idea is simple: (1) a customer purchases a SPOT watch from Microsoft (other companies make similar watches as well),[27] and (2) the watch receives customized data on an FM subcarrier. Thus, Microsoft has figured out a way to use one of the most densely used areas of spectrum to send data to customers.

4. Conclusions: A Cup Half Full, a Cup Half Empty

The FM radio frequency range occupies only a very small part of the "beachfront property" (it occupies only 20.5 MHz of bandwidth, which is less than .05 percent of the frequencies below 3 GHz). Nonetheless, its partial deregulation has allowed one-way transmissions over subcarriers, offering an early example of what markets can do with when deregulation occurs.[28] Thus, in spite of the heavy use of FM radio technology, we have continued to develop new ways to fit services into an otherwise full radio dial. These new services are channeled through a subcarrier in ways that do not impact our radio reception. Subcarrier functions vary from simple displays that show the name of the radio station, reveal the name of the song playing, list weather conditions, etc. Now these subcarrier services are being expanded by the world's largest company, Microsoft, to transmit data to watches. All the same, governments continue to assert the importance of maintaining legacy analog radio broadcasts. However, since governments partially deregulated the FM band, many other products and services have been developed to fit within this frequency range. These products are still only capable of receiving transmissions, for the government does not yet allow consumer devices to transmit data back to the companies that send them information (unless those devices can be connected to the Internet).

[26] *See* Arik Hesseldahl, *Suunto in the SPOTlight*, FORBES.COM, March 31, 2003, *available at* http://www.forbes.com/2003/03/31/cx_ah_0331tentech.html (last visited March 4, 2004) (describing the launch of Microsoft's Smart Personal Objects Technology and the company's forthcoming products).

[27] *See Microsoft SPOT Watches Go on Sale in January*, INFOWORLD.COM, December 16, 2003, *available at* http://www.infoworld.com/article/03/12/16/HNmsspot_1.html (last visited February 20, 2004) (describing the functionality of SPOT and the various watches that are now on the market).

[28] The Low-Power FM Case offered the possibility for communities and small operators to use available portions of the FM spectrum for low-power broadcasts. Although the rulemaking procedure for low-power FM broadcasts resulted in somewhat of a regulatory failure, the keen interest among consumer groups to gain access to more of the spectrum nonetheless comes through loud and clear.

III. MID-LOW BANDS: 200 MHZ TO 1,000 MHZ (200 MHZ TO 1 GHZ)

This band will be analyzed in the following two separate segments: 200 to 600 MHz ("Segment A") and 600 to 1,000 MHz ("Segment B").

A. Analysis of Segment A: 200 to 600 MHz

Figure 2 shows measurements for the mid-low band of radio frequencies from 200 MHz to 600 MHz.

1. Broadcasting Television and T-DAB

The peaks seen in the graph show that broadcasting television and Terrestrial Digital Audio Broadcasting (T-DAB) frequencies are being used. However, frequency "use" refers only to transmission upon these frequencies; the data does not indicate how many devices are in fact listening to these broadcasts. Recall that under the principle of point-to-multipoint broadcast, transmissions occur and occupy the same bandwidth regardless whether they are being listened to or not. By way of metaphor, these broadcasts can be compared with someone speaking into a microphone that is connected to an amplifier. Although the person is speaking, there is no way to tell if anyone is in fact listening to that person.

This distinction between broadcast transmission on allocated frequencies and the public's use of broadcast frequencies is critical. For example, in Belgium cable is very inexpensive, and cable penetration is very close to 100 percent.[29] Thus, it is likely that the majority of the population of Brussels receive their television signals via cable rather than by wireless broadcast. In this particular case, it may make more sense to subsidize the handful of television viewers in Brussels who do not have cable service and provide them with it (this proposal is an extrapolation of the "Negroponte switch" concept).[30] As a result, the broadcast television frequencies would be freed up for other uses (*e.g.*, wireless Internet or high-speed mobile data services). Of course, not all nations have a high cable penetration; as such, different strategies may be appropriate for different countries. However, regardless of the fact that much of the broadcast spectrum remains unexploited, International Telecommunications Union (ITU) regulations stipulate that the same frequencies must be allocated for television broadcast to all countries in the world regardless of their cable penetration.

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[29] *See* "European Union Information Society Indicators in the Member States of the European Union," *available at* http://www.eu-esis.org/Basic/basic2000_7.htm (last visited March 5, 2004) (noting that Belgium has one of the highest cable penetrations in the world).

[30] The "Negroponte switch" holds that one of the main aspects of technological convergence is that the generation that grew up receiving their information by wire (*e.g.*, telephones) and vice versa (*e.g.*, cable) would see their children receive the data in the opposite fashion (*i.e.*, wireless telephones and cable televisions). As Phil Weiser has pointed out in his forthcoming treatise on telecommunications policy, Negroponte himself has suggested that others may have suggested this idea first, but George Gilder's constant use of the term "Negroponte switch" gave that idea staying power. *See* Nicholas Negroponte, *Wireless Revisited*, WIRED.COM, August 1997, *available at* http://www.wired.com/wired/archive/5.08/negroponte_pr.html (last visited March 5, 2004) (describing the Negroponte switch).

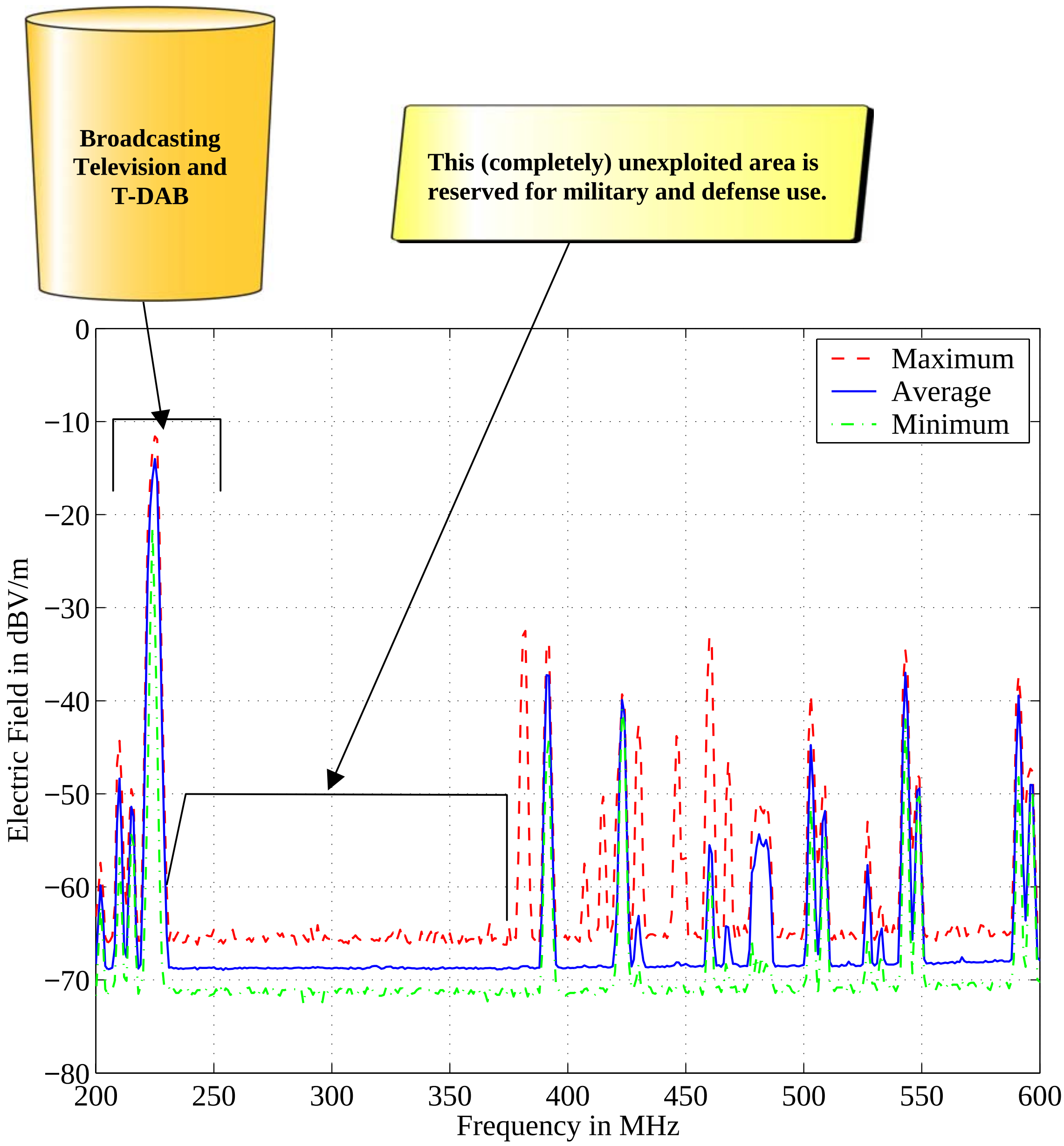

Figure 2 Graph showing the mid-low band spectrum sample (Segment A), 200 MHz to 600 MHz.

2. Military and Defense Allocations

The military has 173.4 MHz of spectrum allocated to it, which is roughly eight times greater than the 20.5 MHz of bandwidth allocated to the FM band. Whereas the FM band is highly used, we detected almost *no use* within the wide range of frequencies allocated to the military (the only exceptions were found at the end of the spectrum). Of course, it is possible that these frequencies are being used elsewhere in the country (*e.g.*, beyond the reach of our transmitters). In addition, it is possible that these frequencies could prove beneficial in case a military or national need arises. After the 9/11 terrorist attacks, for example, radio services played a vital role in rescue efforts.[31]

Military and emergency use of this allocated frequency is sacrosanct. In spite of the fact that militaries worldwide have control over 40-50 percent of the prime spectrum, there is no publicly available data that explains how much spectrum the military really uses or needs—such data is top secret. Our test results, however, show good reason to question the military's need for so large an amount of the spectrum. Recall that our test took place only a few kilometers from NATO headquarters, one of the world's largest military centers. Though the spectrum showed no activity during our test period, NATO nonetheless claims to use this spectrum for the following purposes:

- Military aircraft communications in general
- Naval military communications
- Military satellite communications
- Tactical air functions such as airborne surveillance, control data transmission, and air-to-air communications
- Tactical ground communications, which serves as one of the backbone frequency bands for land forces[32]

Of course, such applications of these military frequencies may well be vital to national defense efforts, especially in the wake of 21st-century terrorist activities. If this large frequency allocation can be justified, that allocation should not be reduced. Thus, although it is perhaps unreasonable to ask the military to disclose the type of applications or transmissions being used, it might be reasonable to expect the military to demonstrate a legitimate need for the exclusive possession of so large a segment of the wireless spectrum.

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[31] See Robert Galvin and James Schlesinger (eds.), "Spectrum Management for the 21st Century," CSIS Panel Report, October 2003, at 5 (describing the importance of the radio spectrum during the 9/11 response).

[32] *See* NATO Basic Fact Sheets, Cooperation in Radio Frequency Management, December 1, 2000, *available at* http://www.nato.int/docu/facts/crfm.htm (last visited February 13, 2004).

B. Analysis of Segment B: 600 to 1,000 MHz

Figure 3 shows measurements for the mid-low band of radio frequencies from 600 MHz to 1,000 MHz.

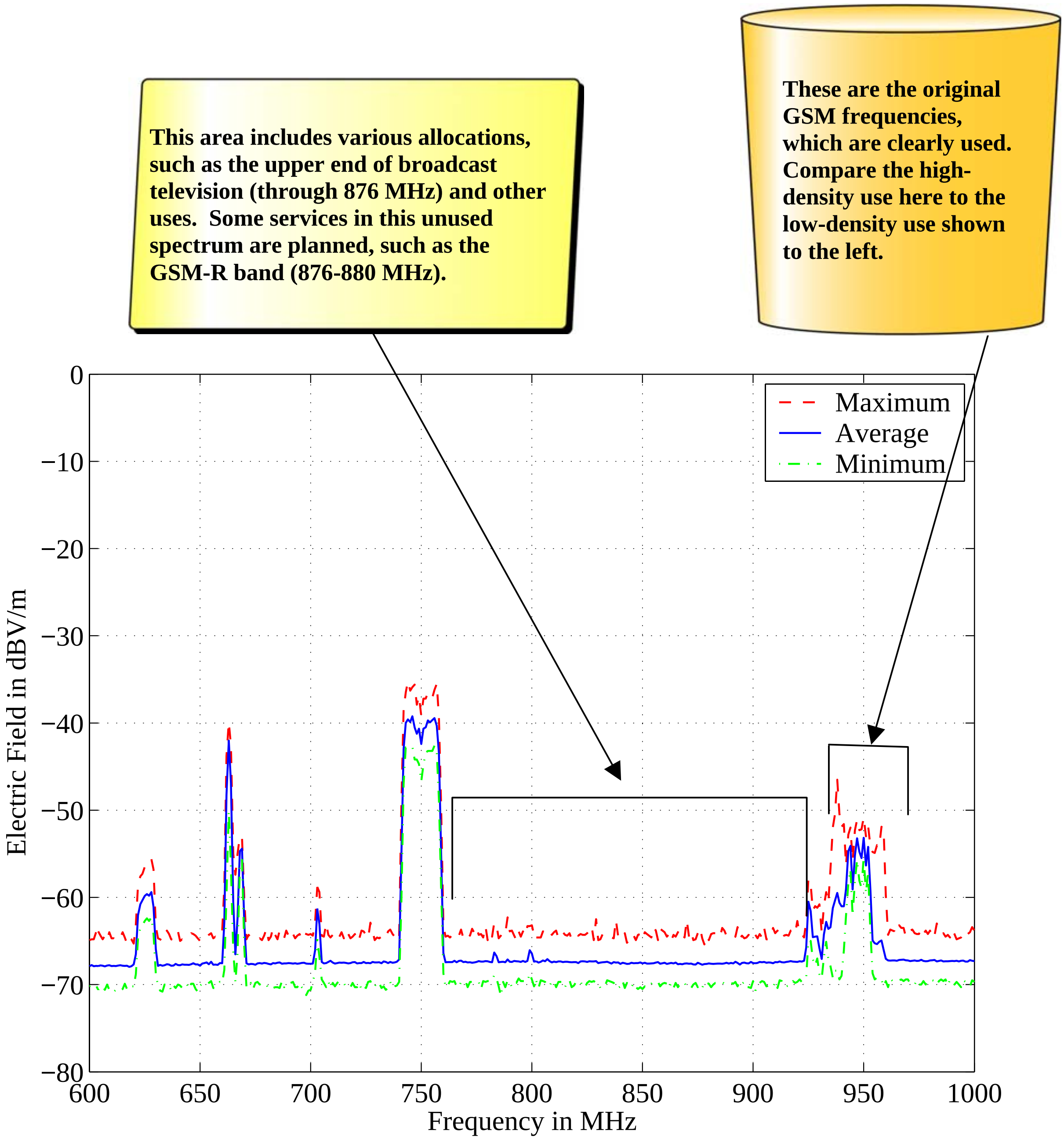

Figure 3 Graph showing the mid-low band spectrum sample (Segment B), 600 MHz to 1,000 MHz.

The unused segment of frequencies beginning roughly at 750 MHz is allocated mostly to broadcast television (and to a few other miscellaneous services). As seen in the graph, these frequencies are unused in Brussels. Of course, the neighboring frequencies allocated to GSM are highly used. The data shown in the preceding graph thus provides a classic example of the argument that scarcity is not an innate characteristic of the spectrum resource, but is instead caused by inadequate government allocation of that resource. The government, then, has decided to allocate only a small amount of the spectrum to GSM (which is clearly used) and a large amount to broadcast television (which remains largely unused). This unused broadcast spectrum could be used for any number of services (*e.g.*, wireless telephony or wireless Internet), but government regulations require that it be used only for broadcast television.

IV. MID-HIGH BANDS: 1,000 TO 6,200 MHZ

These bands will be analyzed in the following two separate segments: 1,200 MHz to 2,200 MHz ("Segment A") and the entire band, 1,000 MHz to 6,200 MHz ("Segment B").

A. Analysis of Segment A: 1,200 to 2,200 MHz

Figure 4 shows the mid-high band spectrum sample (Segment A), 1,200 MHz to 2,200 MHz. The discussion in this section closely mirrors the one in the previous section. A large amount of frequency is allocated for military and defense use (this area is mainly unused); however, the neighboring mobile telephony services are highly used. This data leads to the following question: Does the military need such a large spectrum allocation?

B. Analysis of Segment B: 1,000 to 6,200 MHz

Figure 5 shows the large range of frequencies from 1 GHz to 6.2 GHz (Segment B). Note that we detected very little activity beyond 2 GHz, as the frequency capacity to penetrate obstacles greatly deteriorates beyond this range. Accordingly, the value of these frequencies declines as well. Further, it is interesting to observe that, though there are hundreds of Wi-Fi sites in downtown Brussels, we did not identify any Wi-Fi activity in the 2.4 GHz range (the range in which Wi-Fi devices operate). We were probably unable to detect any activity because these devices operate at low power.

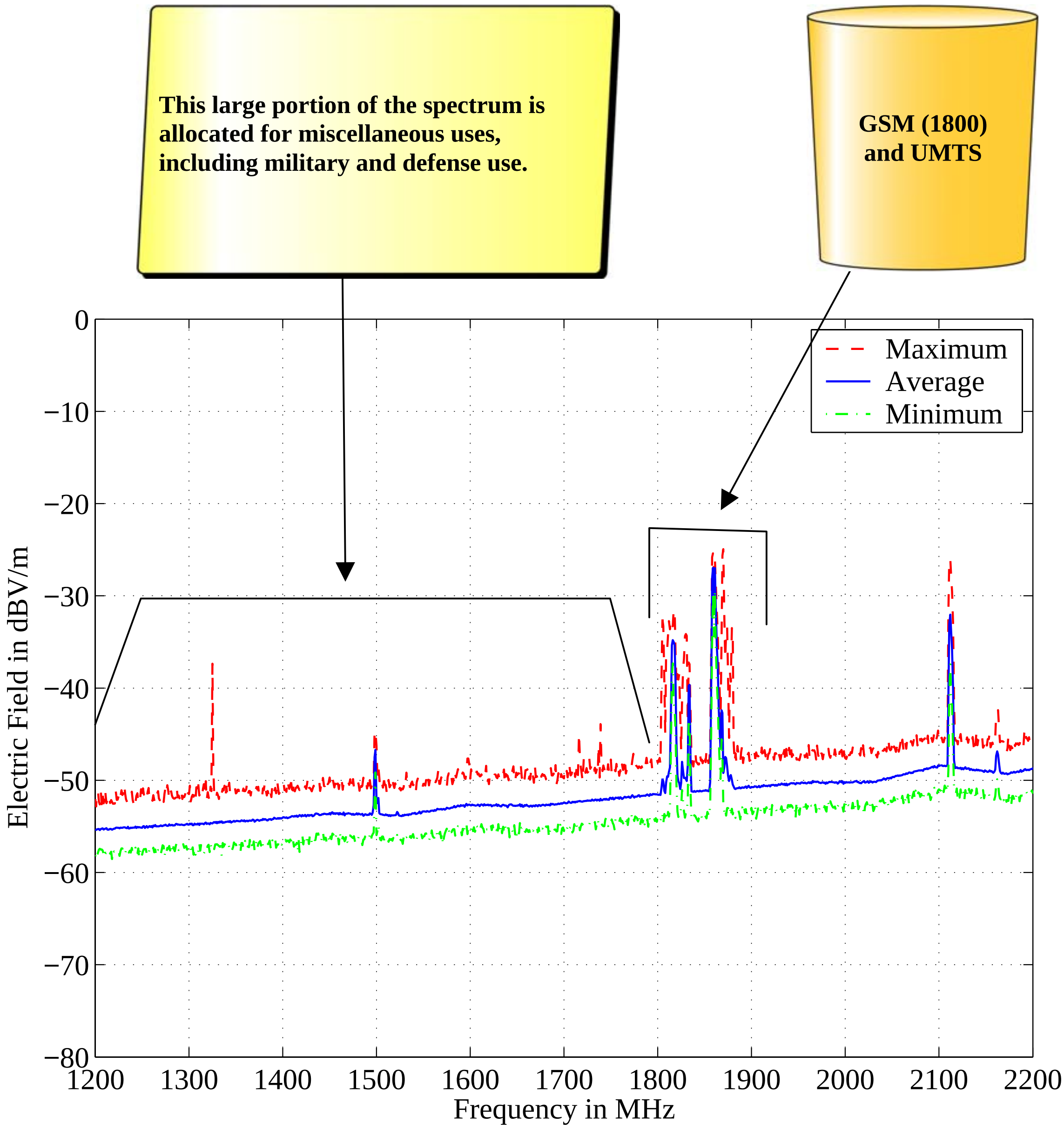

Figure 4 Graph showing the mid-high band spectrum sample (Segment A), 1,200 MHz to 2,200 MHz.

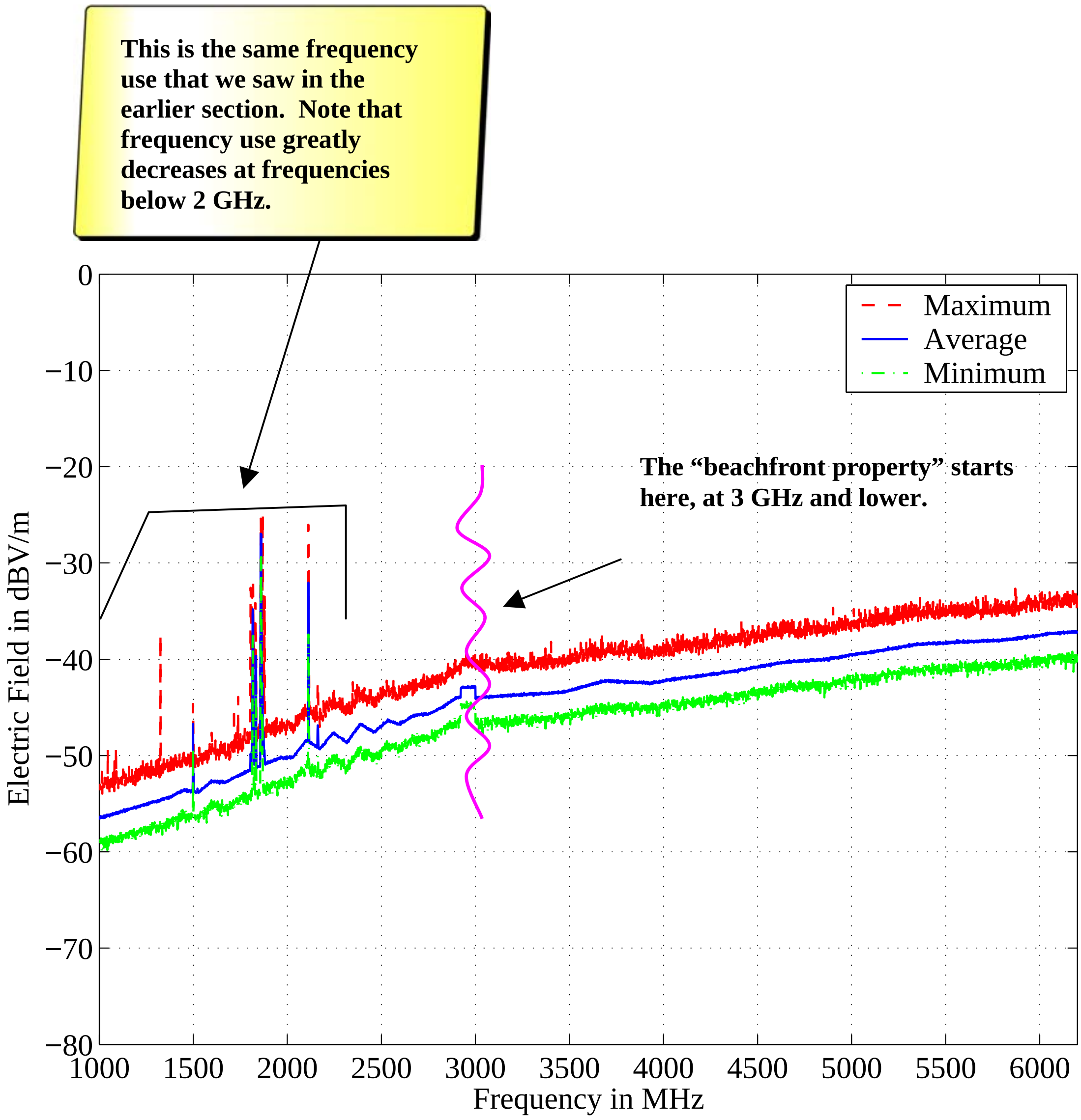

Figure 5 Graph showing the mid-high band spectrum sample (Segment B), 1,000 MHz to 6,000 MHz.

V. SOFTWARE-DEFINED RADIO AND ULTRA-WIDEBAND

In spite of the fact that every single frequency is allocated, sometimes for multiple uses, our data shows extremes of frequency use and disuse within the 30 MHz to 6,200 MHz range that we tested. Thus, sizeable frequency ranges are largely underused (*e.g.*, broadcast television and military frequencies), while other frequency ranges are heavily used (*e.g.*, FM radio and mobile telephony frequencies). It should be fairly self-evident that centralized planning efforts have not led to the balanced use of spectrum.

One of the aims of this chapter is to point out the fact that largely unused portions of the spectrum can be exploited by employing new technologies such as software defined radio (SDR) and ultra-wideband (UWB).

SDR can be configured to "listen before talking," and it can be configured to exploit only unused parts of the radio spectrum. Thus, SDR products would appear to be good candidates for the use of areas of the spectrum that are frequently idle, such as military and broadcast television frequencies. A consumer SDR device could, for example, be programmed so that it does not use frequencies reserved for military communications during emergency situations (in such cases, it would operate in other frequency bands). Thus, SDR devices could make use of bands that are already allocated to other users without interfering with the principle underlying use of those bands.

The promise of UWB is even greater that that of SDR. UWB operates at the "noise floor," which means that it operates at very low power, below the threshold of normal transmissions. In reviewing the graphs in this chapter, we can see that virtually all transmissions occur above –60 dBV/m. Since UWB applications are designed to operate below this noise threshold, their transmissions can occur throughout the entire spectrum range without disrupting other applications.

VI. BROADCAST TELEVISION

A. Flipping the "Negroponte Switch"

Broadcast television is one of the largest private occupiers of wireless spectrum in the valuable *mobile-use* frequency ranges below 3 GHz.[33] In fact, broadcast television uses the same analog spectrum that it has used since its inception. Furthermore, television is generally an enterprise that doesn't encourage human movement; in other words, people generally watch television from a fixed position, and they generally don't bring their televisions with them as they move about. For this reason, if frequencies continue to be allocated for broadcast television (an assumption that we should question, since most people view television by cable), those frequencies should be the less valuable higher frequencies (*e.g.*, above 5 GHz). People could use these broadcast frequencies by simply connecting an outdoor antenna to the television with a wire.

Broadcast television is, in many ways, at the heart of many centrally planned allocation problems. For example, Andrew Lippman, the Director of MIT's Media Lab, recently declared that academics who are part of the open spectrum movement are embracing the idea that "electrical engineering in the old sense of the word is largely over."[34] In this same posting to the "open spectrum" listserv (hosted by the

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[33] Frequencies below 3 GHz have the best propagation characteristics for penetrating obstacles and therefore do not need an outside antenna to be used.

[34] *See* MIT Openspectrum Discussion Lists, posts by Andrew Lippman on December 9, 2003, *available at* http://listserv.media.mit.edu/pipermail/openspectrum/2003-December/000992.html (last visited December 10, 2003).

MIT Media Lab), Lippman made an additional claim (one that we have not yet reviewed), noting that "[t]wenty years ago, we made this point with respect to digital information representations, now it is important for digital communications."[35] Here, Lippman is probably referring to early observations that led to Nicholas Negroponte's now famous axiom[36] that the generation that grew up receiving their television by the airwaves and their telephone calls by wire would see their children do just the opposite (*i.e.*, this generation would receive their television over cable and make telephone calls using wireless handsets).[37] This maxim has come to be known as the *Negroponte switch.*

The switch is happening slowly. At present, there are no serious discussions underway to move television frequencies up into higher bands that are most suitable for fixed uses. However, there are plans in Europe and in the United States to "switch *over*" from broadcasting to digital, also within ranges below 3 GHz (this process is also called the "analog switch *off*").[38] The idea is that the inefficiently used analog airways can be freed up for other uses, and the resulting spectrum can be "refarmed" [a concept employed by the International Telecommunications Union (ITU)].[39] For the time being, however, cable penetration may approach 100 percent in many countries (such as Belgium), but airwaves will still be allocated for television broadcast (even though those airwaves will be hardly used by the great majority of consumers who instead have cable or satellite).[40]

However, even if these digital frequencies are not used in places where cable penetration is high, they may be used elsewhere in the world where cable penetration is lower. And, most importantly, the new digital allocations occupy less spectrum and offer improved services (*e.g.*, as many as six channels can fit into a single analog channel); therefore, these allocations are evidence of progress being made in the right direction. In addition to improved spectrum usage, the quality of the picture is higher and sound quality is improved.[41] However, despite these obvious advantages, the

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[35] *Id.*

[36] Nicholas Negroponte is the Chairman of the MIT Media Lab.

[37] NICHOLAS NEGROPONTE, BEING DIGITAL 24 (1996).

[38] *See* ANDREAS GRÜNWALD, ANALOGER SWITCH-OFF: ZUR VERWALTUNG TERRESTRISCHER RUNDFUNKFREQUENZEN IM ZEICHEN DER DIGITALISIERUNG DER FERNSEHÜBERTRAGUNG IN DEUTSCHLAND UND DEN U.S.A (Beck: 2001).

[39] Spectrum refarming is the reallocation of the spectrum to different uses, and this practice is codified in U.S. law, European law, and ITU guidelines and recommendations. *See* "Spectrum Refarming," ITU Document 1B/14, October 18, 1996 (discussing the principles of spectrum refarming).

[40] *See* Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, eEurope 2002 Final Report, COM(2003) 66 final, February 11, 2003, *available at* http://europa.eu.int/eur-lex/en/com/cnc/2003/com2003_0066en01.pdf (last visited March 22, 2004) [hereinafter: Commission Report on eEurope 2002] (noting at 8 that in Belgium … there is nearly 100 percent cable penetration).

[41] *See e.g.*, BIPE Study for the European Commission, Directorate General Information Society, "Digital Switchover in Broadcasting," April 12, 2002, executive summary *available at* http://tinyurl.com/2gsmd (last visited March 20, 2004). The report summarizes the advantages and challenges of the transition. These advantages are summarized as follows: (1) HDTV provides image

switch has yet to occur (except in Berlin),[42] and it may not occur anytime soon.[43] Berlin is ahead of its time, and most commentators believe that it will take another decade (or possible two) before other metropolitan cities worldwide follow suit.[44]

B. The Television Paradox

The television paradox is this: we regularly replace nearly all electronics in our homes on a regular basis, but because of government regulation, televisions are held sacrosanct. This paradox has not been explored in other academic literature, so it is appropriate that we address the topic here. In point of fact, questions regarding the details about a switchover to digital tend to engender great anger and fear, for many seem to believe (1) they have a right to use their televisions for an indefinite period of time and (2) this right should be protected. For example, in a 1998 cover story, BUSINESS WEEK described the future switchover as a "Digital D-Day."[45] This article prompted at least one letter to the editor, which was published the following month. This letter encapsulates the views of many citizens, and it reads as follows:

> I come from a middle-class household, and if I had several thousand dollars burning a hole in my pocket, I would find something to spend it on other than a digital TV. I, for one, refuse to be bullied into purchasing the next state-of-the-art, overpriced toy. I don't plan on replacing a perfectly good TV just because broadcasters and TV manufacturers made it obsolete.[46]

In the preceding letter, the consumer expresses concern that broadcasters and manufacturers are attempting to make a fully functional product obsolete. This consumer's concern, however, is based on an unfortunate misunderstanding. In fact, as we will see below, consumers can purchase a small "set-top box," which sits on top

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quality approaching that of 35 mm film; (2) HDTV provides a picture aspect ratio of 16:9 and a scan line of 1,080 lines (NTSC is 525 lines) (today's technology is about half that quality); (3) digitization allows video, audio, and text information to be compressed for more efficient transmission; (4) digital media put more control in the hands of consumers than do older analog media; (5) more channels provide greater media choice, and easy access for consumers is the driving force of digital convergence; (6) HDTV uses the existing 6 MHz of an analog channel to deliver signals that are far superior to traditional analog television; and (7) this same bandwidth can in fact transmit one full quality (HDTV) signals or up to five or six compressed (SDTV) signals over the same bandwidth (this is called "multicasting" or "multiplexing").

[42] Thomas W. Hazlett, *As Berlin's TVs Go Digital, Airwaves Lie Unused*, WALL STREET JOURNAL EUROPE, November 24, 2003, *available at* http://www.manhattan-institute.org/html/_wsj-as_berlins_tvs.htm (last visited March 20, 2004) [hereinafter: Hazlett, Berlin Switch]. Hazlett notes that "The "Berlin Switch" is so far an international novelty. Other nations are likely to spend a tedious decade (or two) pushing away from analog signal standards."

[43] FCC regulations assume an analog switch-off in 2006, but that because of a loophole in the law, it is not expected to happen until, at the earliest, a decade later.

[44] See Hazlett, Berlin Switch, cited *infra* at note 42.

[45] Catherine Yang, Neigl Gross, & Richard Siklos, *Digital D-Day,* BUSINESS WEEK, October 1998 (describing the planned transition to digital television).

[46] Stacie Sybrandt, Letter to the Editor, BUSINESS WEEK, November 16, 1998.

of existing television sets and allows continued reception of digital services (and many more channels). In short, many people fear that they will need to replace their units with new ones, when in fact no such replacement needs to be made.

The 88 EUR[47] ($110) needed to purchase a set-top box seems like a small price to pay for the opportunity to free up this grossly underused and yet extremely valuable spectrum. These are the first such products on the market. The first Wi-Fi devices cost around $1,000, and within a year after launch their price dropped by eighty percent to $200. Even if the first-generation product price of $110 does not drop by a similar percentage (*i.e.*, to $25), the prices are nonetheless bound to fall. Furthermore, so long as governments provide ample preparation time for the switchover (*e.g.*, two-three years), most consumers will be able to afford them and enjoy the added benefits and features that they bring to their viewing experience. And, even if we had to replace the *entire* television set—which we do not—such an expectation would not be unreasonable, especially when weighed against similar expectations established for many other electrical products that we own. Virtually all other electronic and mechanical products need to be replaced every few years, because of wear or because of obsolescence. While some products like dishwashers and hot water heaters have fairly long lifecycles (they are replaced on average every eleven-twelve years),[48] it is perhaps more useful to compare similar baskets of goods (much like economists do). If we examine lifecycle data for electronic equipment, we see that many products must be replaced fairly often. For example, computers generally last three years[49] (software lasts even less time),[50] and, indeed, *almost all* audiovisual technology purchased in the 1980s will no longer work in today's world (radios and televisions, which are protected by the government, are notable exceptions). In those few cases where the technology does still work, that technology must use equipment that is no longer available for purchase in today's consumer products market. Some examples of this dated technology include the following:

- Eight-track cassette tapes[51]
- Vinyl records[52]

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[47] This price estimate is based on real data from the first switchover, which took place in Berlin. *See* the discussion below.

[48] Kathy Prochaska-Cue, "Study on Average Life Expectancies for Large Ticket Items," University of Nebraska Working Paper, April 2002.

[49] *See* KPMG consulting White Paper, "Technology Set-Aside," November 2002. The paper notes the lifecycles of different high technology products. The white paper states that personal computers have an average lifecycle of three years and that computer hardware in general (*e.g.*, computers, printers, routers, and bridges) have a lifecycle that ranges from two to five years.

[50] *Id*. (noting the average lifecycle for software is one to three years, although versions are often available for "update" at a nominal fee).

[51] Eight-track cassettes were very popular in the United States during the 1970s, although the format never really made it to Europe. The devices have not been manufactured since the late 1970s or early 1980s. *See* Doug Hinman & Jason Brabazon, "The Rise and Fall of the 8-Track," 1994, *available at* http://www.bway.net/~abbot/8track/history.html (last visited March 20, 2004).

[52] Technically, vinyl records are still alive, and many audiophiles believe that (in spite of the static) they provide a more "natural" sound. However, for all practical purposes, they have been replaced by

- Betamax video tapes (see the discussion below)
- Kodak "Disc" cameras[53]
- Dot-matrix printers[54]
- First-generation analog cell phones[55]
- Rotary-dial telephones[56]
- Laser discs[57]

Granted, comparing the obsolescence of different devices may be somewhat misleading, for each product has its own lifecycle. However, the point is this: every electromechanical device, regardless of its lifecycle, needs to be replaced at some point or another. In the case of televisions and radios, the difference is that they are usually replaced, not with newer versions that have digital, high-definition capabilities (as has been the case with other audiovisual products), but instead with versions that contain outdated and (what would otherwise be obsolete) technology. Remote controls have replaced knobs, color has replaced black and white, and the form and style of the devices are sleeker than they were in the 1970s. However, the underlying technology is unchanged because regulators have mandated that it remain frozen in time. These "dumb," one-way, receive-only devices have practically no interactive component.[58] Thus, a well-preserved television from 1950 tends to work just as well

CDs. *See* Kevin Hunt, *Still Many Ways to Take Vinyl Out for a Spin*, THE TORONTO STAR, October 2, 2003 (noting that there are a few manufacturers that make the equipment to play vinyl records, but that the majority of distributors have totally discontinued manufacture of new music on this media format, so they are generally only useful for antique collections).

[53] Disc cameras were a novel format introduced by Kodak in 1982 and discontinued in 1989. Kodak stopped selling film for the cameras in 1999. *See* Kodak Press Release, "Kodak Disc Film to Be Discontinued by 1999," Rochester, N.Y., January 24, 1997, *available at* http://www.toptown.com/nowhere/kypfer/DISCdiscontinued.htm (last visited March 22, 2004).

[54] Although some people still use dot-matrix printers, obtaining ink, replacement parts, and specialized perforated printing paper is very difficult.

[55] The first generation telephones in the United States will no longer work on most networks, as they have all been upgraded to either TDMA or CDMA technology.

[56] Rotary-dial telephones will still work on older networks, but not in all cities. Many have phased out the recognition of the rotary "pulses" in favor of touch tones. One of the reasons that they have been phased out is because these rotary phones and their pulses were a security risk—and they were part of a legacy telephone network that has since migrated to computers. For an overview and discussion on the security aspects of old telephone networks (a concept called "phreaking"), *see* Ryan, Wardriving, cited *supra* at note 2.

[57] The "laser disc" was an early digital format that was sold in the United States from about 1992 to 1997. It was high-quality, however the discs were very large (about the size of a phonograph). They made some progress in U.S. households; however, in 1997 the DVD delivered a "killer blow" to the product, and laser discs are no longer available. *See DVD Delivering Killer Blow to Laser Disc*, SCREEN DIGEST, December 1, 1997.

[58] An exception to this rule is the "teletext" function, which exists in several countries. This

in 2004 as it did back when it was manufactured. Although newer HDTV standards are now coming on the market, many consumers see no need to purchase them because these consumers have come to rely on the implied government promise to keep their televisions from obsolescence.

One item that has not yet made this list is the VHS-standard VCR, although studies show that these products are already being phased out in favor of the DVD recordable products that are on the market today.[59] So, as this chapter is being completed, the epitaph for the VCR is being written. Before we mourn its passing, we might remember that old devices and technologies are regularly replaced by newer devices and technologies that are faster, more efficient, better designed, and full of the kinds of innovative and helpful features that consumers demand. Generally speaking, the public benefits from technology upgrades.

Figure 6 shows the timetable during which VHS standard tape recorders replaced Betamax (Beta) recorders in the United States. It is possible that a similar graph will be drawn within the next twelve to twenty-four months as DVD recorders continue to displace VCRs in the marketplace.

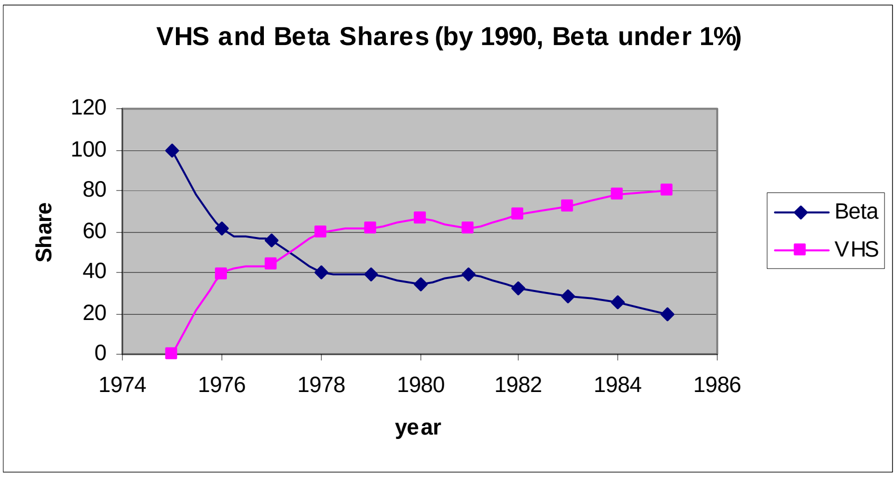

Figure 6 As the above figure shows, by 1977 the VHS standard had overtaken the market share of Sony's Betamax product. Sony discontinued the product in 1985 and started manufacturing VHS products instead.

The difference between these technologies in general and television in particular is that the free market has enabled companies to freely develop and market them. Television's long history of regulation, on the other hand, is closely tied to

function is, however, seldom used, and it is only a *cable* function, not a broadcast function. Therefore, it does not fall within the scope of this discussion.

[59] *See* Walter S. Mossberg, *Prices for DVD Recorders Fall but Devices Are Hard to Use*, WALL STREET JOURNAL, March 10, 2004, at D1 (describing the new DVD recorders that are out on the market and noting the prices are dropping low enough for consumers to consider them as viable replacements for VHS systems).

spectrum regulation. However, note that Betamax, VHS, and DVD technologies are all connected to television technology, and they even cost almost as much as a small television (sometimes more, at least early in their lifecycle).[60] Almost every household that has a television also has a VCR,[61] and many now have VCRs *and* DVD players.[62] (The sale of VCRs increased in spite of failed attempts by Universal Studios[63] and by the Motion Picture Association to suppress them).[64] Yet in spite of their willingness to purchase these add-ons, consumers still believe that the televisions themselves should not need to be replaced.

In fact, in order to refarm spectrum and receive a new signal, one does not need to buy a new television; instead, one only needs to purchase a small, relatively inexpensive "set-top box." In Berlin, early versions of these set-top boxes sold for as little as 88 EUR in late 2003,[65] and prices are likely to drop over time as more markets

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[60] *Id.* (noting that only recently have the prices for DVD recorders fallen below $1,000 per unit).

[61] An FCC study completed in 2000 shows that VCR penetration in U.S. households was close to eighty-five percent. *See* http://www.fcc.gov/Bureaus/Common_Carrier/Notices/2000/fc00057a.pdf (last visited March 14, 2004).

[62] *See* FCC Press Release, "FCC Releases Tenth Annual Report on Competition in Video Markets, January 28, 2004, *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-243261A1.pdf (last visited March 22, 2004), noting that households have a wide variety of video products at their disposal. With regard to VCRs and DVDs, the press release notes the following:

> In 1994, VCR penetration was 84 percent of TV households. In 2003, Nielsen Media Research estimates VCR penetration at 91 percent of TV households. Our 1998 Report was the first Report in which the FCC reported that DVD technology, introduced in 1997, would likely replace laser disc technology as another means to view video programming. The number of homes with DVD players has grown rapidly since their introduction, and DVDs have made significant impact on the home video market. In the first half of 2003 alone, equipment manufacturers sold 10.3 million DVD players.

[63] *See Sony Corp v. Universal City Studios*, 464 U.S. 417 (1984). Universal Studios attempted to outlaw VCRs, under a concern that VCRs would undermine their business. The Supreme Court found that the making of individual copies of complete television shows for home use is considered "fair use" and that the manufacture of devices to facilitate such recording is legal. This decision was a close call, however—the Supreme Court's vote was five to four, and had one vote been different, VCRs would have been held to be illegal.

[64] Jack Valenti, president of the Motion Picture Association, famously asserted that "the VCR is to the American film producer and the American public as the Boston strangler is to the woman home alone." Fred von Lohmann, *Betamax Was a Steppingstone*, MERCURY NEWS, January 25, 2004, *available at* http://www.mercurynews.com/mld/mercurynews/7793111.htm (last visited March 24, 2004) (quoting Jack Valenti). *See also* Comments of the Electronic Frontier Foundation, MB Docket No. 02-230, December 6, 2002, *available at* http://bpdg.blogs.eff.org/archives/eff-comments.pdf. Noting that the VCR was vehemently attacked by the Motion Picture Association and by its President, Jack Valenti, who testified before a House Subcommittee in 1982 as follows:

> But now we are facing a very new and a very troubling assault on our fiscal security, on our very economic life and we are facing it from a thing called the video cassette recorder and its necessary companion called the blank tape. And it is like a great tidal wave just off the shore. This video cassette recorder and the blank tape threaten profoundly the life-sustaining protection, I guess you would call it, on which copyright owners depend, on which film people depend, on which television people depend and it is called copyright.

[65] *See* Hazlett, Berlin Switch, cited *supra* at note 42.

are opened.[66] It is a relatively simple piece of electronics, and it would not be unreasonable to assume that these products could sell for as little as 20 EUR ($25) per device once they are mass produced. However, for reasons that are highly political, governments continue to use analog spectrum and to protect consumers from having to purchase these new devices. One study commissioned by the U.K. government found that "[s]witchover is an unpopular policy. After being informed of the practicalities and implications of switchover, 38 percent of respondents agreed with switchover and 50 percent disagreed."[67] Clearly, governments and regulators have considerable work to do in order to help the public understand the benefits of digital television.

C. Use of Analog Television in Belgium

At this stage, many might ask the following question: How often is analog spectrum used? On average, only eleven percent of the analog television spectrum is used in the United States. Further, as part of our analysis of the Brussels spectrum usage data, we scanned the use and occupancy of the television spectrum. Below are the graphs of the tests broken down into two segments, channels 21–38 (segment 1) and channels 39–60 (segment 2).

In segment 1 (channels 21–38), shown in Figure 7, we detected activity in five out of eighteen channels. In other words, only twenty-eight percent of the channels allocated for television spectrum was actually used for broadcasts. In segment 2 (channels 39–60), shown in Figure 8, we detected significant activity in four out of twenty-two channels, with one additional channel demonstrating some activity that slightly exceeded –60 dBV/m. Thus, even though this signal level is too low to receive a quality broadcast (it is probably from a rural area outside of Brussels), we shall include it in our calculation. In sum, in this segment, twenty-two percent of the channels allocated to broadcast are used for that particular purpose.

[66] Details on set-top boxes can be found on a website organized for the Berlin switchover, *available at* http://www.digitalfernsehen.de/ (last visited March 22, 2004).

[67] *See* Jeremy Klein, Simon Karger, & Kay Sinclair, "Attitudes to Digital Switchover," prepared for the United Kingdom Department for Culture, Media and Sport, March 30, 2004, *available at* http://www.digitaltelevision.gov.uk/publications/pub_attitudes_to_switchover.html (last visited March 31, 2004). The study concluded that the switchover is unpopular for three major reasons: (1) the government seems to be coercing people by threatening that their "analog television will be 'taken away,'" (2) consumers do not trust government motives, and (3) consumers fear they will have to pay to purchase a new television. *Id.*, at 13.

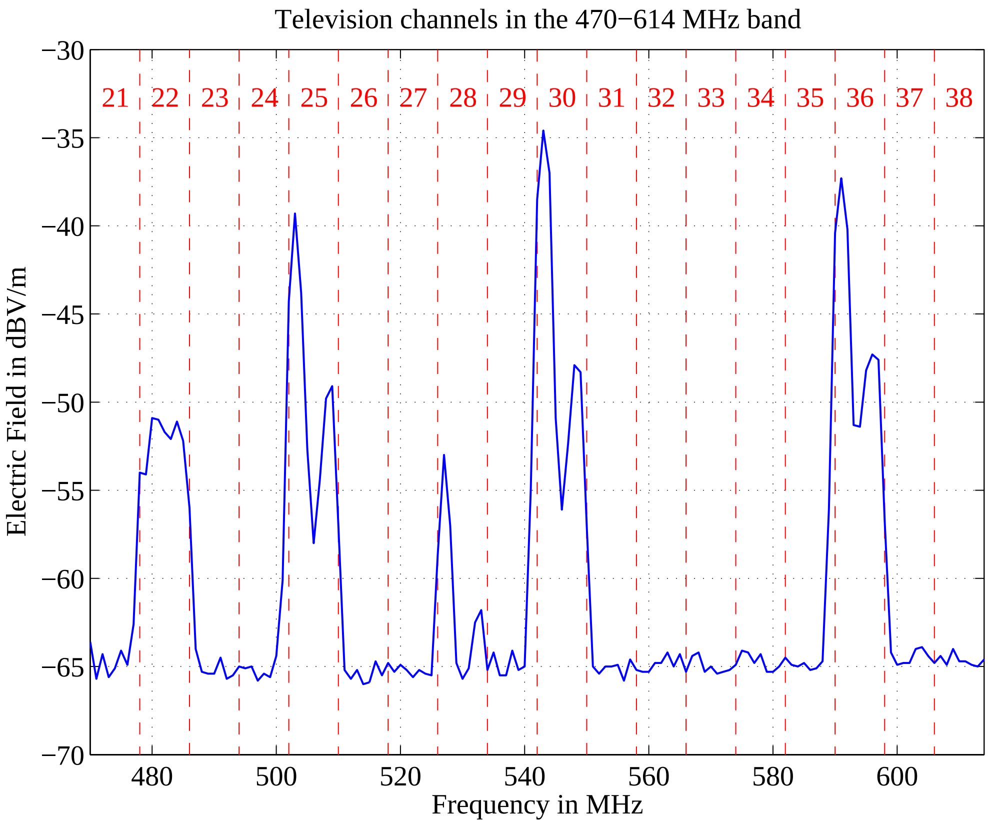

Figure 7 This graph shows the scan of channels 21 through 38. These channels are based on the joint ITU/BIPT allocation tables, which will be discussed in the attached Annex.

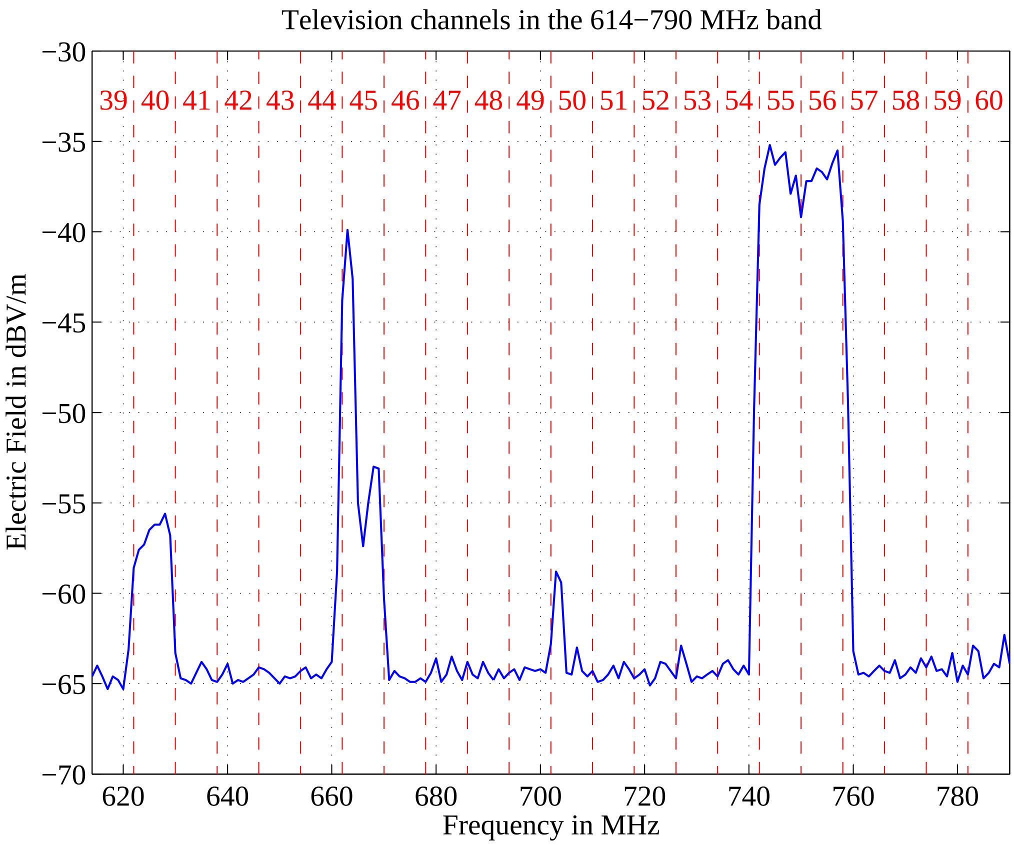

Figure 8 This graph shows the scan of channels 39 through 60. These channels are based on the joint ITU/BIPT allocation tables, which will be discussed in the attached Annex.

D. Europe and the United States: The Allocations Are Similar, but the Numbers May Deceive

There are additional channels allocated for television use in Belgium that we did not analyze. For example, we did not provide a breakdown of use in frequency bands I and III, and it is likely that the use may be less than has already been noted. Table 1 shows a full list of the frequencies that are allocated to radio and television, according to the ITU, for Region 1, which includes Europe and Africa.

Frequency Band	Range	Allocation	Channels
I	41–68 MHz	TV, Radio	2–4
II	87.5–108 MHz	FM Radio	—
III	174–230 MHz	TV	5–12
IV	470–606 MHz	TV	21–37
V	606–862 MHz	TV	38–60

Table 1 The official ITU allocations for Region 1. *Source*: ITU.

Note that the television allocations are similar, but not identical, to the allocations in the United States. However, roughly the same amount of bandwidth has been allocated in both the United States and Europe. Table 2 shows the corresponding allocations in the United States. (Note that the terminology is somewhat different: Europe uses designations I through V, whereas the United States uses VHF and UHF designations.)

Frequency Band	Range	Allocation	Channels
VHF	54–72 MHz	TV	2–4
VHF	76–88 MHz	TV	5–6
VHF	88–108 MHz	FM Radio	--
VHF	174–216 MHz	TV	7–13
UHF	470–608 MHz	TV	14–36
UHF	614-806 MHz	TV	38–69

Table 2 The allocations to television and radio in the United States. *Source:* ITU.

Based on our empirical analysis in Brussels, nine of the forty channels were being used for broadcast. Said another way, over three quarters (seventy-eight percent) of the channels that are allocated for analog broadcast are not used. In truth, however, the situation is probably even worse. Of course, broadcast is a one-to-many proposition, and there is no way to tell how many people are actually listening or tuning in to the broadcast. As it turns out, since Brussels has nearly 100 percent cable penetration,[68] it is likely that there are few listeners to the already limited broadcasts. Thus, the Negroponte switch has already happened in Belgium, meaning that people are receiving their television by cable rather than by the airwaves. Nonetheless, because of the continued use of the spectrum for analog broadcasts, the country is reaping none of the benefits that could be seen from opening this spectrum up for other uses.

VII. CONCLUSION

Cellular telephony was proven in a lab in 1949, though it did not advance because frequencies were not made available for it. In fact, the first mobile (cellular) licenses in the United States were granted as the result of the reallocation of television's unused UHF channels 70-83 by the FCC in 1968.[69] However, even though it has been empirically proven that broadcasters do not use most of the channels below 70, those channels are squatted upon by their users. While an imperfect expression, "squatting" is an appropriate term in this instance because, like land that has been squatted upon, the channels cannot be used for other purposes unless the squatters either give up their possession of those channels or are evicted.

[68] See Commission Report on eEurope 2002, cited *supra* at note 40.

[69] Malcom W. Oliphant, *The Mobile Phone Meets the Internet*, IEEE SPECTRUM, Volume 36, Number 9 (August 1999). Archive issues *available at* www.spectrum.ieee.org.

As we have seen, many channels are not even used; however, because they are allocated for use to specific broadcasters for broadcasting purposes, we *assume* that they are used. If our empirical test of spectrum use in Brussels is accurate (the results appear to be similar to those concluded from tests in the United States, as cited by Thomas Hazlett), then these frequencies could—and should—be allocated for other technologies (*e.g.*, 3G). Even better, they could be opened up to allow new uses like SDR and UWB, as well as provide room for other technologies that do not require allocation at all (Wi-Fi, for example, can share frequencies without causing interference).

In Europe, television broadcast “squatting” is not as pronounced as it is the United States, though it is close. In 1961, the European Conference of Post and Telecommunications (CEPT) more or less standardized television broadcast stations per country [the Stockholm (1961) Agreement][70] and is already making some headway towards the study and implementation of a digital plan that will make more efficient use of these channels through an analog switch off,[71] much like the one that took place in Berlin. However, the manner in which the process will continue elsewhere in Europe is as yet unknown.

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[70] Draft EEC Report 4, “Initial Ideas Concerning the Revision of the Stockholm (1961) Agreement,” January 2002, *available at* www.ero.dk/doc98/Official/Pdf/ECCRep004.pdf.

[71] The Commission published a Call for Tender in October 2002 (OJ S195 of 08.10.2002), *available at* http://ted.eur-op.eu.int/static/doccur/en/en/153347-2002.htm?SID=&time=Tue%2. Also, the Commission published a comprehensive report on the topic in April 2002: Study by BIPE for DG INFSO on the Digital Switchover in Broadcasting, *available at* http://europa.eu.int/information_society/topics/telecoms/regulatory/studies/documents/final_report_120402.pdf.

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REPORT

KATHOLIEKE
UNIVERSITEIT
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LEUVEN, 04-02-28

ANNEX

Measurement of the spectrum occupancy in the city centre of Brussels.

Authors: Prof. dr. ir. Emmanuel Van Lil, ir. Jan Potemans

Commissioned by Prof. dr. Jos Dumortier and Patrick Ryan (ICRI) on 2004-01-08

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1) Description of the problem

It was the purpose to measure the spectral occupancy in a large city. The purpose of those measurements was not to pinpoint some low occupancy bands, but to check the interference possibilities to new, more advanced systems like UWB systems. Indeed, all frequencies are assigned by international agreements in the WARC (World Administrative Radio Conference) conferences and this measurement is no reason to “claim” unused frequency bands. Indeed, some are for instance reserved for distress signals. The absence of measurement data at that frequency just indicates that no airplane emergency happened on that day. The actual frequency assignments, as enforced by the Belgian Federal Communication Authorities (BIPT-IBPT), can be found on web site and are added in appendix A at the end of this report to allow an easy interpretation of the measurements. To obtain relatively high values, the measurement antennas where put on the rooftop of a seven storey building close to the inner boulevards of Brussels, namely on the building of the N.V. Astrid (the security communication system of the Belgian authorities) (see “antenna location” on Fig. 1). Indeed a low antenna f.i. carried by a pedestrian walking between high buildings only receives diffracted and reflected fields, which are lower than the fields present on the roofs of the buildings. The measurements in this report are hence a worst case. The measurements were performed on 24-27 February, 2004 (Tuesday-Friday). To cover the frequencies from 30-6200 MHz we have used three antennas, each covering a band of less than 3 octaves (30-200 MHz, 200-1000 MHz and 1000-6200 MHz). With each antenna a full day (24 hours) of measurements was performed, so that also conclusions could be drawn on the variation of the occupancy during day and night. Only weekdays were tested, so no weekend traffic was measured, since the building was closed on weekends.

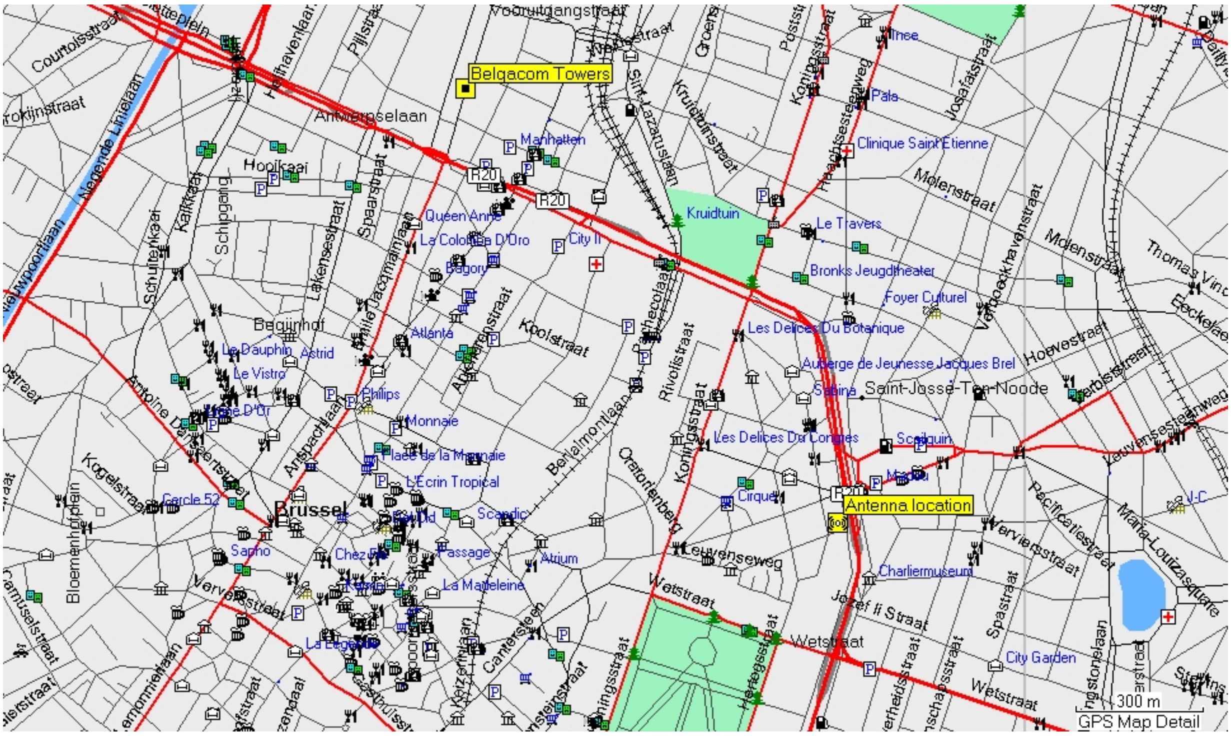

Fig. 1: Location of the measurement antenna on a Brussels map.

2) Discussion of the measurement set-up

The spectrum analyser (an HP 8595E with serial number 3677U00842) and the PC, used to collect the data through an IEEE488 interface were located in a technical room on the 6^{th} floor of the building. Fig. 2 shows the set-up inside the building as well as Patrick Ryan and Manu Van Lil discussing a trace on the spectrum analyser. Every 5' a sample of the spectrum was taken (duration about 1").

Fig. 2: Setup of the measurement equipment inside the building.

The spectrum analyser was connected to the antenna on the roof via a 36 m long cable, which had an attenuation of 3 dB at 400 MHz. This value can be extrapolated to other frequencies (all frequencies in MHz) with the formula:

$$AttdB(f) = AttdB(400)\sqrt{(f/400)} \tag{1}$$

Hence, a correction between 0.8 dB at 30 MHz and 11.8 dB at 6200 MHz has been performed on the measurements to obtain the values at the antenna terminal.

The measurements are further converted to effective electric field strengths, since the received signal always depends on the gain of the receiving antenna. Above 30 MHz, the following formula is valid:

$$E(dBV_{eff}/m) = AF(dB/m) + P(dBm) - 13 \tag{2}$$

with E the electric field strength, AF the antenna factor and P the measured power.

The antenna factor is provided by the “laboratorium De Nayer”, an accredited institution for EMC measurements, associated with the industrial engineering school of the same name, for the two antennas below 1 GHz, that they have provided to us for those measurements, and taken from specifications for the antenna above 1 GHz. The frequency dependence of the 3 antenna factors can be seen from **Table 1**, **Table 2** and **Table 3**. For intermediate frequencies, linear interpolation was used.

Table 1: Antenna factors for the biconical antenna.

MHz	dB/m
30	13.3
40	12.2
50	11.6
60	10.4
70	7.4
80	7.8
90	10.87
100	12.9
120	16.2
140	12.6
160	15.2
180	17.1
200	16.4

Table 2: Antenna factors for the log-periodic antenna.

MHz	dB/m
200	11.9
250	12.8
300	15.9
400	16.4
500	19.6
600	21.4
700	25.4
800	24.1
900	26.4
1000	28.4

Table 3: Antenna factors for the horn antenna.

GH	dB/m
1	24.3
2	27.6
3	30.9
4	32.8
5	34.3
6	34.8
7	36.5
8	37.4
9	37.9
10	38.8
11	38.7
12	38.7
13	40.0
14	41.7
15	38.9
16	38.3
17	40.4
18	46.6

The field strengths are a property of the environment, and can furthermore be compared to the field values that are allowed by Belgian law (they are half of the European ones, so the power is ¼ of the values allowed in the rest of Europe). The most important and lowest values are the ones valid for the general public, i.e. for a continuous 24 h/day exposure 7 days a week. If one never exceeds the cumulative value (for all transmitters in the spectrum) of 14 V_{eff}/m or 22.9 dBV_{eff}/m, full compliance with the Belgian standards is guaranteed. Above 400 MHz and below 10 MHz, larger field values are allowed.

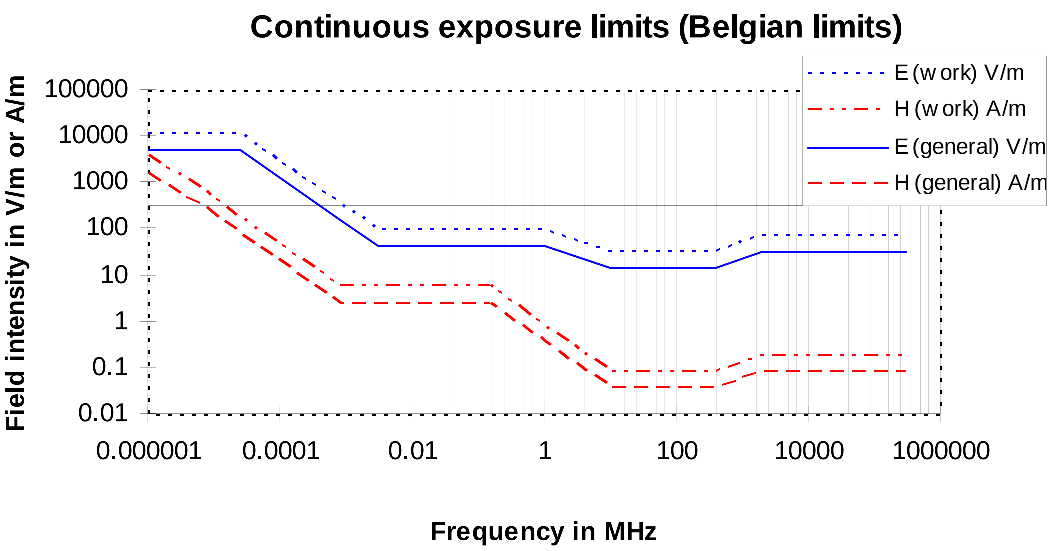

Fig. 3: Belgian Electric and Magnetic Field exposure limits.

Let us now discuss consecutively the measurements on the three different bands.

a) For the first measurement, the biconical antenna was tilted (Fig. 4), so that signals with both polarisations could be measured (with a small loss in accuracy, max. 3 dB). The antenna had a nearly omnidirectional pattern, so that most signals in Brussels were picked up, except a zone of about 10 degrees around the axis of the antenna. This corresponds with neglecting the signals coming from essentially the orange zone in Fig. 5 (due to the antenna tilt, only signals from airplanes in the left (uncoloured) zone (between the purple lines) will be strongly attenuated).

Fig. 4: Biconical antenna (EMCO 3104, serial number 2980).

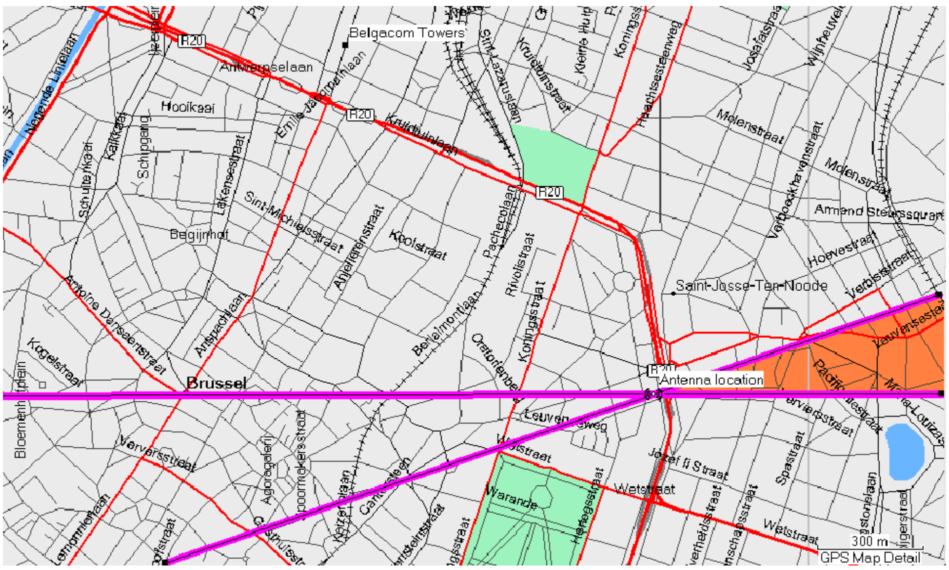

Fig. 5: Zones from which signals may not be picked up (or are significantly attenuated).

The measurements were started on Tuesday February 24 at 11:20 AM and continued till 11:20 AM the next day (289 measured spectra). The plot of the spectrum is shown in Fig. 6. The highest value was -7.8 dBV/m (an FM transmitter in the 88-108 MHz frequency band), or about 34.5 times below the allowable field values and hence 1189 times below the allowable power values. This means that 1189 transmitters of the same power will generate sufficient power to reach the legal maximum. Note that the time scale continues after midnight with higher values (25=1:00 AM, 26=2:00 AM, etc.). It is obvious that radio FM transmitters are continuously transmitting, while communication systems are coming up in a more stochastic way. A 3-dimensional view of the same picture is displayed in Fig. 7.

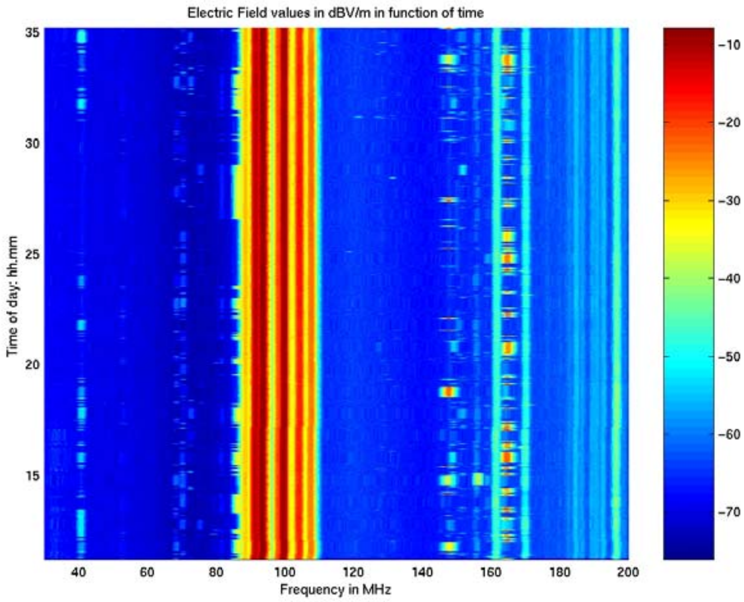

Fig. 6: Electric Field in dBV/m between 30 and 200 MHz.

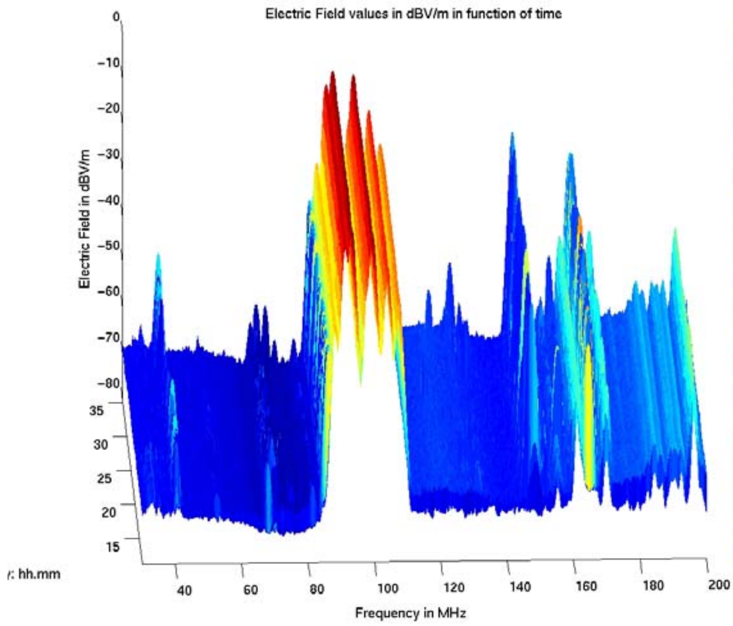

Fig. 7: 3-D view of the Electric Field in dBV/m between 30 and 200 MHz.

b) For the second measurement, the log-periodic antenna was also tilted (Fig. 8), like in the previous case, so that signals with both polarisations could be measured (with a small loss in accuracy, max. 3 dB). We rotated the antenna, until the highest signals were noticed. This antenna had a more directive pattern, so that only signals coming from the Northern part of Brussels within an angle between 100 and 180 degrees were picked up. They are shown as a green zone in Fig. 9. This zone includes the building of our biggest mobile operator (Proximus).

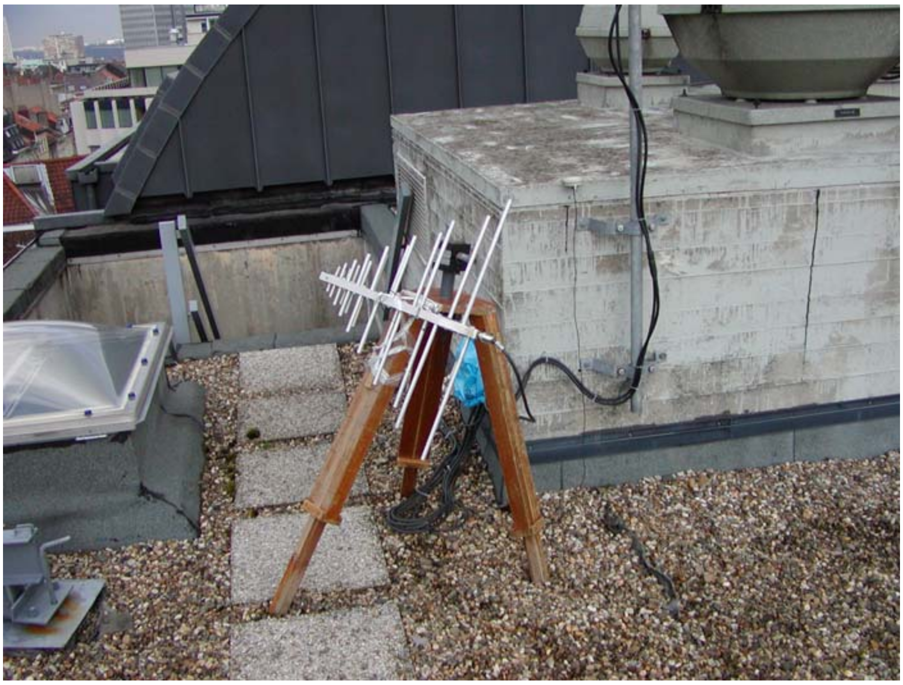

Fig. 8: Log-periodic antenna.

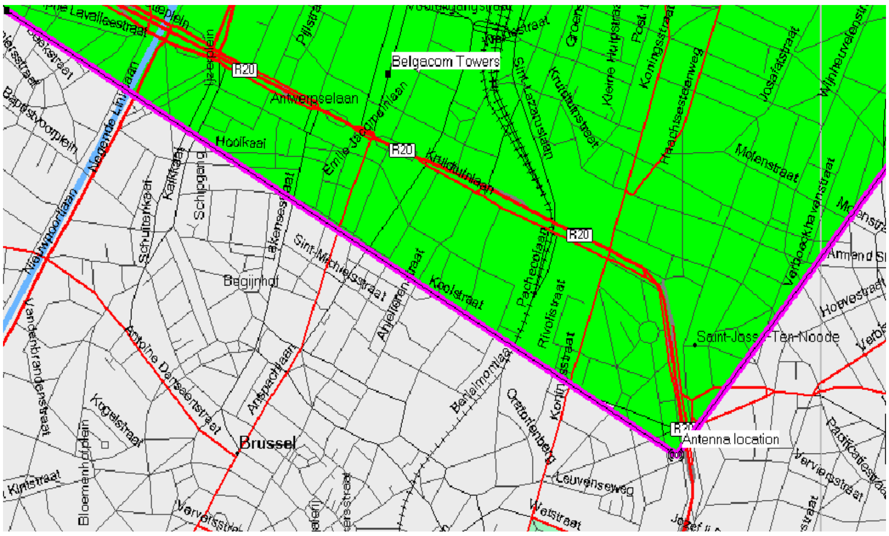

Fig. 9: Zone from which signals are picked up (signals from other areas are significantly attenuated).

The measurements were started on Wednesday February 25 at 12:05 noon and continued till 13:25 (PM) the next day (305 measured spectra). The plot of the spectrum is shown in Fig. 10. The highest value in this frequency band was -11.6 dBV/m (a DAB-T (Terrestrial Digital Audio Broadcast transmitter) from the VRT=Flemish public radio and TV network) transmitter around 226 MHz, or about 53.1 times below the allowable field values and hence 2818 times below the allowable power values. This means that 2818 transmitters of the same power will reach the legal maximum. Note that again the time scale continues after midnight with higher values (25=1:00 AM, 26=2:00 AM, etc.). The two first lines after the DAB line are respectively TETRA and classical trunking systems. It is obvious that the TV transmitters (seen as a dual bar, one for the video carrier and one for the audio carrier) are continuously transmitting, while communication systems are coming up in more stochastic way. The highest band is the GSM-900 band. There we see clearly the traffic disappearing at night, while the GSM broadcast channels (BCH) obviously have to stay on. Another high value is noticed around 750 MHz. This is apparently a DVB-T (Terrestrial Digital Video Broadcast) transmitter from the RTBF=French public radio and TV network. A 3-D view of the same picture is shown in Fig. 11.

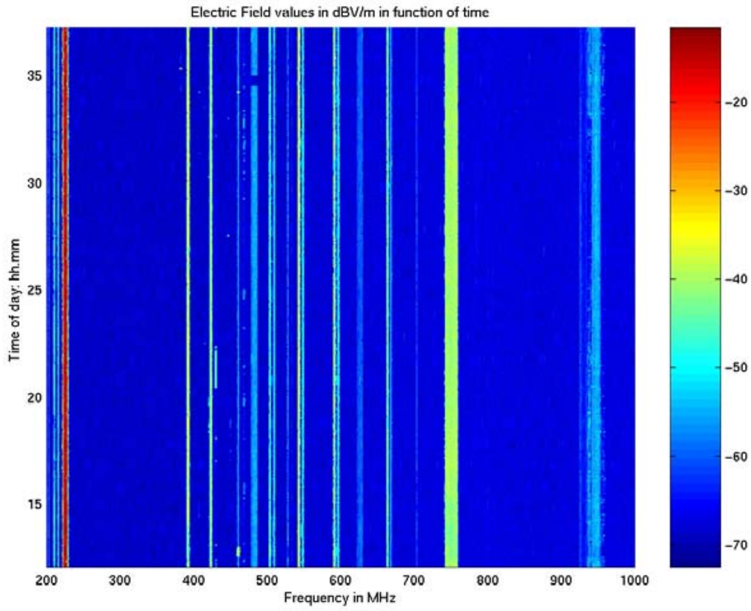

Fig. 10: Electric Field in dBV/m between 200 MHz and 1 GHz.

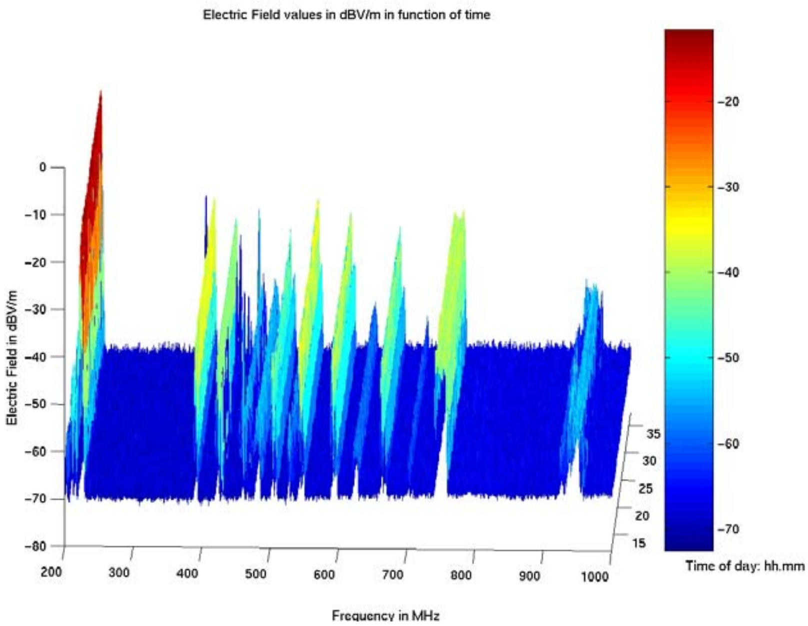

Fig. 11: 3-D view of the Electric Field in dBV/m between 200 MHz and 1 GHz.

c) For the last measurement, the horn antenna was kept horizontal (Fig. 12), since enough depolarisation occurs above 1 GHz. We rotated the antenna, until the highest signals were noticed. This antenna has the most directive pattern, so that only signals coming from the part of Brussels within an angle of about 40 degrees were picked up. This green zone in Fig. 13 includes most of the official buildings of Brussels (both national ministerial buildings and European community buildings), all situated in the "law street" (Wetstraat).

Fig. 12: 1-18 GHz exponential horn antenna.

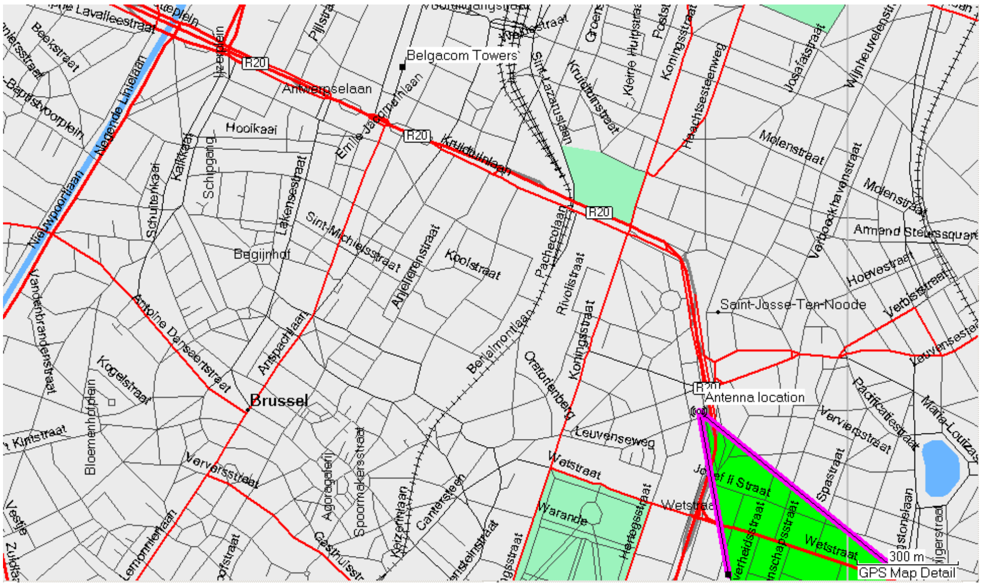

Fig. 13: Zone from which signals are picked up (signals from other areas are significantly attenuated).

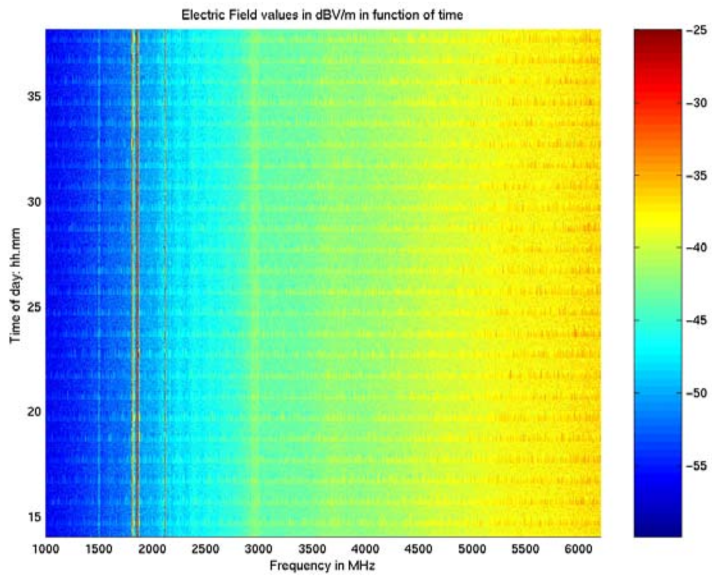

Fig. 14: Electric Field in dBV/m between 1 and 6.2 GHz.

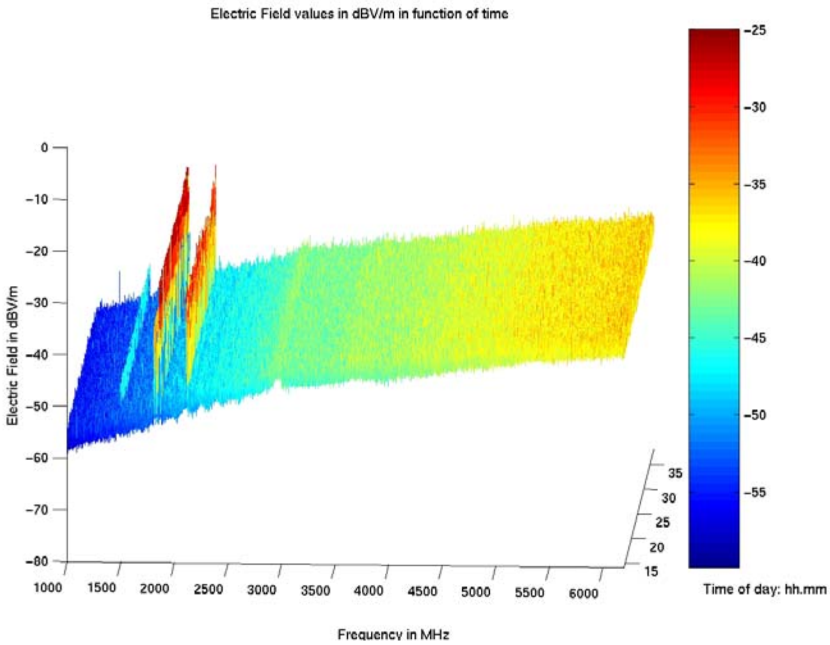

Fig. 15: 3-D view of the Electric Field in dBV/m between 1 and 6.2 GHz.

The measurements were started on Thursday February 26 at 14:05 and continued till 14:20 the next day (292 measured spectra). The plot of the spectrum is shown in Fig. 14. The highest value in this frequency band was -24.9 dBV/m (a GSM-1800 transmitter), or about 246.7 times below the allowable field values and hence 60848 times below the allowable power values. Note that again the time scale continues after midnight with higher values (25=1:00 AM, 26=2:00 AM, etc.). We did not notice the snowfall that started at 6:30 AM on Friday, since snow is nearly not attenuating those frequencies. Only GSM-1800 and UMTS are noticed. We are obviously not in the reach of wireless networks (802.11 like). A 3-dimensional view of the same picture is displayed in Fig. 15.

3) Conclusions and acknowledgements

This survey has shown both that radiation is well below the admissible limits and that some parts of the spectrum might be useful for new applications at the condition that they don't interfere with existing applications.

We are greatly indebted to ir. Kristof De Paepe and ir. Olivier Anizet, as well as the other personnel from ASTRID to have allowed us to place our measurement equipment in their premises, as well as to Prof. Dirk Van Troyen and ing. Jan De Vos from the "Laboratorium De Nayer" for providing us with the measurement antennas below 1 GHz. Finally, we thank the commissioners for funding these measurements.

Heverlee, 27 February 2004

Prof. dr. ir. E. Van Lil (K.U.Leuven)

APPENDIX A: International Frequency Allocations.

Note: a black second column means that the band is ONLY allocated to military applications, a white ONLY to civilian applications and a grey is a mixed civilian and military band (source: web site of the BIPT).

Frequency Band		Allocation	Application
9-14 kHz		not allocated	*Medical implants* (Foreseen) *Inductive applications* On-site paging
14-19.95 kHz		MARITIME MOBILE	*Medical implants* (Foreseen) *Inductive applications* *Maritime military systems* On-site paging
19.95-20.05 kHz		not allocated	*Medical implants* (Foreseen) *Inductive applications* On-site paging
20.05-70 kHz		FIXED MARITIME MOBILE	*Medical implants* (Foreseen) *Inductive applications* *Maritime military systems* On-site paging Point-to-Point
70-72 kHz		not allocated	*Medical implants* (Foreseen) *Inductive applications*
72-84 kHz		FIXED	*Medical implants* (Foreseen) *Inductive applications* Point-to-Point
84-130 kHz		not allocated	*Medical implants* (Foreseen) *Inductive applications*
130-148.5 kHz		FIXED	*Medical implants* (Foreseen) *Inductive applications* (9-135 kHz) Point-to-Point Tracking systems *Inductive applications* (135-148.5 kHz) (Foreseen) Amateur (135.7-137.8 kHz)
148.5-255 kHz		not allocated	*Medical implants* (Foreseen)
255-283.5 kHz		AERONAUTICAL RADIONAVIGATION	*Medical implants* (Foreseen) Beacons (aeronautical)
283.5-315 kHz		AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION	*Medical implants* (Foreseen) Beacons (aeronautical) Beacons (maritime) *Defence systems*
315-405 kHz		AERONAUTICAL RADIONAVIGATION	Beacons (aeronautical) *Defence systems*
405-415 kHz		not allocated	*Defence systems*
415-435 kHz		AERONAUTICAL RADIONAVIGATION MARITIME MOBILE	Maritime communications *Defence systems*
435-495 kHz		MARITIME MOBILE	Maritime communications *Defence systems*
495-505 kHz		MOBILE (distress and calling)	GMDSS

505-526.5 kHz		MARITIME MOBILE	*Defence systems* Maritime communications
526.5-1606.5 kHz		BROADCASTING	*AM sound analogue*
1606.5-1625 kHz		MARITIME MOBILE	*Defence systems* Maritime communications
1625-1635 kHz		not allocated	*Defence systems*
1635-1800 kHz		FIXED MARITIME MOBILE	*Defence systems* Maritime communications Point-to-Point
1800-1810 kHz		not allocated	*Defence systems*
1810-1830 kHz		MOBILE except aeronautical mobile	Amateur *Defence systems* Maritime communications
1830-1850 kHz		AMATEUR	Amateur
1850-2000 kHz		MOBILE except aeronautical mobile	*Defence systems* Maritime communications
2000-2025 kHz		not allocated	*Defence systems*
2025-2045 kHz		MOBILE except aeronautical mobile (R)	*Defence systems*
2045-2160 kHz		LAND MOBILE MARITIME MOBILE	*Defence systems* Maritime communications
2160-2173.5 kHz		not allocated	*Defence systems*
2173.5-2190.5 kHz		MOBILE (distress and calling)	GMDSS
2190.5-2300 kHz		not allocated	*Defence systems*
2300-2498 kHz		MOBILE except aeronautical mobile (R)	*Defence systems*
2498-2502 kHz		not allocated	
2502-2625 kHz		FIXED MOBILE except aeronautical mobile (R)	*Defence systems* Point-to-Point
2625-2650 kHz		not allocated	*Defence systems*
2650-2850 kHz		FIXED MOBILE except aeronautical mobile (R)	*Defence systems* Point-to-Point
2850-3025 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
3025-3155 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
3155-3230 kHz		FIXED MOBILE except aeronautical mobile (R)	*Inductive applications* (Foreseen) *Defence systems* Point-to-Point
3230-3400 kHz		FIXED MOBILE except aeronautical mobile	*Inductive applications* (Foreseen) *Defence systems* Point-to-Point
3400-3500 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
3500-3800 kHz		AMATEUR FIXED MOBILE except aeronautical mobile	Amateur *Defence systems* Point-to-Point
3800-3900 kHz		AERONAUTICAL MOBILE (OR) FIXED LAND MOBILE	*Defence systems* Point-to-Point
3900-3950 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
3950-4000 kHz		FIXED	Point-to-Point
4000-4063 kHz			Point-to-Point

		Defence systems
4063-4152 kHz	MARITIME MOBILE	Maritime communications
4152-4172 kHz		*Maritime military systems*
4172-4438 kHz		Maritime communications
4438-4650 kHz	FIXED MOBILE except aeronautical mobile (R)	*Defence systems* *Euroloop* (4.515 MHz) Point-to-Point
4650-4700 kHz	AERONAUTICAL MOBILE (R)	Aeronautical communications
4700-4750 kHz	AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
4750-4850 kHz	FIXED	Point-to-Point
4850-4995 kHz	FIXED LAND MOBILE	Point-to-Point
4995-5060 kHz	not allocated	
5060-5450 kHz	FIXED	*Defence systems* Point-to-Point
5450-5480 kHz	not allocated	*Defence systems*
5480-5680 kHz	AERONAUTICAL MOBILE (R)	Aeronautical communications
5680-5730 kHz	AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
5730-5900 kHz	FIXED	Point-to-Point
5900-5950 kHz	not allocated	
5950-6200 kHz	BROADCASTING	*AM sound analogue*
6200-6233 kHz	MARITIME MOBILE	Maritime communications
6233-6261 kHz		*Maritime military systems*
6261-6525 kHz		Maritime communications
6525-6685 kHz	AERONAUTICAL MOBILE (R)	Aeronautical communications
6685-6765 kHz	AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
6765-7000 kHz	FIXED	Point-to-Point *ISM* (6765-6795 kHz) *Non-specific SRDs* (6765-6795 kHz) *Anti-theft induction systems* (6785-6795 kHz)
7000-7100 kHz	AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
7100-7300 kHz	BROADCASTING	*AM sound analogue*
7300-7350 kHz	not allocated	
7350-8195 kHz	FIXED	Point-to-Point *Anti-theft induction systems* (7400-8800 kHz)
8195-8300 kHz	MARITIME MOBILE	*Anti-theft induction systems* Maritime communications
8300-8340 kHz		*Anti-theft induction systems* *Maritime military systems*
8340-8815 kHz		*Anti-theft induction systems* (7400-8800 kHz) Maritime communications
8815-8965 kHz	AERONAUTICAL MOBILE (R)	Aeronautical communications
8965-9040 kHz	AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
9040-9400 kHz	FIXED	Point-to-Point

9400-9500 kHz		not allocated	
9500-9900 kHz		BROADCASTING	*AM sound analogue*
9900-9995 kHz		FIXED	Point-to-Point
9995-10005 kHz		not allocated	
10005-10100 kHz			
10100-10150 kHz		Amateur	Amateur
10150-11175 kHz		FIXED	*Defence systems* Point-to-Point
11175-11275 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
11275-11400 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
11400-11600 kHz		FIXED	Point-to-Point
11600-11650 kHz		not allocated	
11650-12050 kHz		BROADCASTING	*AM sound analogue*
12050-12100 kHz		not allocated	
12100-12230 kHz		FIXED	Point-to-Point
12230-12368 kHz		MARITIME MOBILE	Maritime communications
12368-12420 kHz			*Maritime military systems*
12420-13200 kHz			Maritime communications
13200-13260 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
13260-13360 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
13360-13570 kHz		FIXED	*Defence systems* Point-to-Point *Anti-theft induction systems* (13553-13567 kHz) *ISM* (13553-13567 kHz) *Non-specific SRDs* (13553-13567 kHz)
13570-13600 kHz		not allocated	
13600-13800 kHz		BROADCASTING	*AM sound analogue*
13800-13870 kHz		not allocated	
13870-14000 kHz		FIXED	*Defence systems* Point-to-Point
14000-14250 kHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
14250-14350 kHz		AMATEUR	Amateur
14350-14990 kHz		FIXED	*Defence systems* Point-to-Point
14990-15010 kHz		not allocated	
15010-15100 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
15100-15600 kHz		BROADCASTING	*AM sound analogue*
15600-15800 kHz		not allocated	
15800-16360 kHz		FIXED	Point-to-Point
16360-16549 kHz		MARITIME MOBILE	Maritime communications
16549-16617 kHz			*Maritime military systems*
16617-17410 kHz			Maritime communications
17410-17480 kHz		FIXED	Point-to-Point
17480-17550 kHz		not allocated	
17550-17900 kHz		BROADCASTING	*AM sound analogue*

17900-17970 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
17970-18030 kHz		AERONAUTICAL MOBILE (OR)	*Aeronautical military systems*
18030-18052 kHz		FIXED	Point-to-Point
18052-18068 kHz		not allocated	
18068-18168 kHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
18168-18780 kHz		FIXED	*Defence systems* Point-to-Point
18780-18846 kHz		MARITIME MOBILE	Maritime communications
18846-18870 kHz			*Maritime military systems*
18870-18900 kHz			Maritime communications
18900-19020 kHz		not allocated	
19020-19680 kHz		FIXED	Point-to-Point
19680-19800 kHz		MARITIME MOBILE	*Defence systems*
19800-19990 kHz		FIXED	Point-to-Point
19990-20010 kHz		not allocated	
20010-21000 kHz		FIXED	Point-to-Point
21000-21450 kHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
21450-21850 kHz		BROADCASTING	*AM sound analogue*
21850-21870 kHz		FIXED	Point-to-Point
21870-21924 kHz		not allocated	
21924-22000 kHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
22000-22180 kHz		MARITIME MOBILE	Maritime communications
22180-22240 kHz			*Maritime military systems*
22240-22855 kHz			Maritime communications
22855-23200 kHz		FIXED	*Defence systems* Point-to-Point
23200-23350 kHz		not allocated	*Defence systems*
23350-24890 kHz		FIXED	*Defence systems* Point-to-Point
24890-24990 kHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
24990-25070 kHz		not allocated	*Defence systems*
25070-25121 kHz		MARITIME MOBILE	Maritime communications
25121-25161.25 kHz			*Maritime military systems*
25161.25-25210 kHz			Maritime communications
25210-25550 kHz		FIXED	*Defence systems* Point-to-Point
25550-25670 kHz		not allocated	
25670-26100 kHz		BROADCASTING	*AM sound analogue*
26100-26175 kHz		MARITIME MOBILE	
26175-27500 kHz		FIXED MOBILE except aeronautical mobile	*Defence systems* Point-to-Point *Eurobalise* (26345-27845 kHz) On-site paging (26500-26960 kHz)

			Anti-theft induction systems (26957-27283 kHz) *ISM* (26957-27283 kHz) *Non-specific SRDs* (26957-27283 kHz) *AM CB* (26960-26990 kHz) *PR 27* (26960-26990 kHz) *Model control* (26990-27000 kHz) *AM CB* (27000-27040 kHz) *PR 27* (27000-27040 kHz) *Model control* (27040-27050 kHz) *AM CB* (27050-27090 kHz) *PR 27* (27050-27090 kHz) *Model control* (27090-27100 kHz) *AM CB* (27100-27140 kHz) *PR 27* (27100-27140 kHz) *Model control* (27140-27150 kHz) *AM CB* (27150-27190 kHz) *PR 27* (27150-27190 kHz) *Model control* (27190-27200 kHz) *AM CB* (27200-27410 kHz) *PR 27* (27200-27410 kHz)
27.5-28 MHz		not allocated	*Eurobalise* (26345-27845 kHz)
28-29.7 MHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
29.7-30.025 MHz		MOBILE	*Defence systems*
30.025-30.2875 MHz			PMR
30.2875-32.4625 MHz			*Defence systems*
32.4625-33.2875 MHz			PMR
33.2875-34.0625 MHz			*Defence systems*
34.0625-36.9875 MHz			PMR *Model aircraft control* (34.995-35.335 MHz) *Model control* (34.995-35.335 MHz) *Radio Microphones* (36.6-36.8 MHz) *Wireless Audio Applications* (36.6-36.8 MHz)
36.9875-37.2625 MHz			*Defence systems* *Radio Microphones* (37-37.2 MHz) *Wireless Audio Applications* (37-37.2 MHz)
37.2625-37.7125 MHz			*Defence systems*
37.7125-39.925 MHz			*Radio Microphones* (37.8-38 MHz) *Wireless Audio Applications* (37.8-38 MHz)

39.925-40.5625 MHz			*Defence systems*
40.5625-40.7 MHz			*Model control* (40.57-40.7 MHz) *ISM* (40.66-40.7 MHz) *Non-specific SRDs* (40.66-40.7 MHz)
40.7-40.7875 MHz			On-site paging
40.7875-40.975 MHz			*Defence systems*
40.975-41.2125 MHz			On-site paging
41.2125-41.725 MHz			*Defence systems*
41.725-41.9875 MHz			On-site paging
41.9875-47 MHz			*Defence systems*
47-68 MHz		BROADCASTING LAND MOBILE	*Land military systems* *TV analogue (terrestrial)* Amateur (50-52 MHz)
68-70.1125 MHz		MOBILE except aeronautical mobile	*Defence systems*
70.1125-70.4125 MHz			PMR
70.4125-71.9875 MHz			*Defence systems*
71.9875-72.5125 MHz			PMR *Model control* (72.0125-72.2625 MHz)
72.5125-74.7875 MHz			*Defence systems*
74.7875-74.8 MHz			
74.8-75.2 MHz		AERONAUTICAL RADIONAVIGATION	ILS
75.2-78.6875 MHz		MOBILE except aeronautical mobile	PMR
78.6875-81.525 MHz			*Defence systems*
81.525-82.5 MHz			PMR
82.5-84.9875 MHz			*Defence systems*
84.9875-87.5 MHz			PMR
87.5-108 MHz		BROADCASTING	*FM sound analogue*
108-117.975 MHz		AERONAUTICAL RADIONAVIGATION	ILS VOR
117.975-121.45 MHz		AERONAUTICAL MOBILE (R)	Aeronautical communications
121.45-121.55 MHz			EPIRBs
121.55-137 MHz			Aeronautical communications
137-137.025 MHz		METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) SPACE OPERATION (space-to-Earth) SPACE RESEARCH (space-to-Earth)	*Space Operations* *S-PCS* *Weather satellites*
137.025-137.175 MHz		METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE OPERATION (space-to-Earth) SPACE RESEARCH (space-to-Earth) Mobile-Satellite (space-to-Earth)	*Space Operations* *S-PCS* *Weather satellites*
137.175-137.875 MHz		METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) SPACE OPERATION (space-to-Earth)	*Space Operations* *S-PCS* *Weather satellites*

		SPACE RESEARCH (space-to-Earth)	
137.875-138 MHz		METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE OPERATION (space-to-Earth) SPACE RESEARCH (space-to-Earth) Mobile-Satellite (space-to-Earth)	*Space Operations* *S-PCS* *Weather satellites*
138-144 MHz		AERONAUTICAL MOBILE (OR) LAND MOBILE	*Defence systems*
144-146 MHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
146-148 MHz		MOBILE except aeronautical mobile (R)	PMR *Wide area paging* (147.15-147.35 MHz)
148-149.9 MHz		MOBILE except aeronautical mobile (R) MOBILE-SATELLITE (Earth-to-space)	On-site paging PMR *S-PCS*
149.9-150.05 MHz		MOBILE-SATELLITE (Earth-to-space) RADIONAVIGATION-SATELLITE	PMR (No new assignments) *S-PCS*
150.05-153 MHz		MOBILE except aeronautical mobile RADIO ASTRONOMY	PMR
153-154 MHz		MOBILE except aeronautical mobile (R) Meteorological Aids	PMR
154-156 MHz		MOBILE except aeronautical mobile (R)	PMR
156-156.5125 MHz			VHF maritime communications
156.5125-156.5375 MHz			SAR (communications)
156.5375-156.7625 MHz			VHF maritime communications
156.7625-156.8375 MHz		MARITIME MOBILE (distress and calling)	SAR (communications)
156.8375-174 MHz		MOBILE except aeronautical mobile	*Medical Telemetry* On-site paging VHF maritime communications (156.8375-157.45 MHz) PMR (157.45-160.6 MHz) VHF maritime communications (160.6-160.975 MHz) PMR (160.975-161.475 MHz) VHF maritime communications (161.475-162.05 MHz) PMR (162.05-169.4 MHz) *Wide area paging* (164.34-164.36 MHz) *Wide area paging* (164.66-164.68 MHz) *ERMES* (169.4-169.825 MHz) PMR (169.825-174 MHz)
174-223 MHz		BROADCASTING LAND MOBILE	Professional radio microphones *T-DAB* (Foreseen) *TV analogue (terrestrial)* *Medical Telemetry* (174-176 MHz)

			On-site paging (174-174.06 MHz) *Radio Microphones* (181.4-184.2 MHz) *Intercom* (181.4125-181.4375 MHz) *Intercom* (184.1625-184.1875 MHz) *Radio Microphones* (202.4-205.2 MHz) *Intercom* (202.4125-202.4375 MHz) *Intercom* (205.1625-205.1875 MHz)
223-226.5 MHz		BROADCASTING	*T-DAB*
226.5-230 MHz		BROADCASTING Fixed Mobile	*Defence systems* *T-DAB* (Envisaged)
230-235 MHz		FIXED MOBILE	*Defence systems*
235-242.95 MHz		FIXED MOBILE Mobile-Satellite	*Defence systems*
242.95-243.05 MHz			EPIRBs
243.05-322 MHz			*Defence systems*
322-328.6 MHz		FIXED MOBILE	*Defence systems*
328.6-335.4 MHz		AERONAUTICAL RADIONAVIGATION	ILS
335.4-380 MHz		FIXED MOBILE Mobile-Satellite	*Defence systems*
380-385 MHz			*Emergency services*
385-390 MHz			*Defence systems*
390-395 MHz			*Emergency services*
395-399.9 MHz			*Defence systems*
399.9-400.05 MHz		MOBILE-SATELLITE (Earth-to-space) RADIONAVIGATION-SATELLITE	
400.05-400.15 MHz		STANDARD FREQUENCY AND TIME SIGNAL-SATELLITE	
400.15-401 MHz		METEOROLOGICAL AIDS MOBILE-SATELLITE (space-to-Earth)	*Defence systems* *Sondes*
401-406 MHz		METEOROLOGICAL AIDS	*Defence systems* *Sondes* *Medical implants* (402-405 MHz) (Foreseen)
406-406.1 MHz		MOBILE-SATELLITE (Earth-to-space)	EPIRBs
406.1-410 MHz		MOBILE except aeronautical mobile RADIO ASTRONOMY	PMR *Radio astronomy*
410-430 MHz		MOBILE except aeronautical mobile	Analogue PAMR PMR TETRA (415-419 MHz) TETRA (425-429 MHz)

430-440 MHz		AMATEUR RADIOLOCATION	Amateur *Defence systems* *ISM* (433.05-434.79 MHz) *Non-specific SRDs* (433.05-434.79 MHz) Detection of avalanche victims (435-495 MHz) (Foreseen) Amateur-satellite (435-438 MHz)
440-450 MHz		MOBILE except aeronautical mobile	Detection of avalanche victims (Foreseen) *Medical Telemetry* PMR *PMR 446* (446-446.1 MHz)
450-470 MHz		FIXED MOBILE	Detection of avalanche victims (Foreseen) *Medical Telemetry* On-site paging PMR On-board communications (457.525-457.575 MHz) On-board communications (467.525-467.575 MHz)
470-608 MHz		BROADCASTING Land Mobile	Detection of avalanche victims (435-495 MHz) (Foreseen) *DVB-T* (Foreseen) Professional radio microphones *TV analogue (terrestrial)* *Medical Telemetry* (470-470.25 MHz) *Radio Microphones* (518-526 MHz) *Radio Microphones* (534-542 MHz)
608-614 MHz		BROADCASTING Land Mobile Radio Astronomy	*Radio astronomy*
614-790 MHz		BROADCASTING Land Mobile	*DVB-T* (Foreseen) Professional radio microphones *TV analogue (terrestrial)*
790-830 MHz		BROADCASTING	*DVB-T* (Foreseen) Radio relay *TV analogue (terrestrial)*
830-838 MHz		BROADCASTING FIXED	*DVB-T* (Foreseen) *Tactical radio relay*
838-862 MHz		FIXED	Radio relay *Tactical radio relay* *Radio Microphones* (854-862 MHz)
862-863 MHz			*Tactical radio relay*
863-870 MHz		FIXED MOBILE except aeronautical mobile	*Tactical radio relay* *Wireless Audio Applications* (863-865 MHz) *CT2* (864.1-868.1 MHz) *Non-specific SRDs* (868-868.6

			MHz) *Alarms* (868.6-868.7 MHz) *Non-specific SRDs* (868.7-869.2 MHz) *Alarms* (869.2-869.3 MHz) *Non-specific SRDs* (869.3-869.65 MHz) *Alarms* (869.65-869.7 MHz) *Intercom* (869.7-870 MHz) *Non-specific SRDs* (869.7-870 MHz)
870-880 MHz		FIXED	*Tactical radio relay* *GSM-R* (876-878 MHz) (Foreseen)
880-885 MHz		MOBILE except aeronautical mobile	*GSM*
885-887 MHz			*CT1+*
887-914 MHz			*GSM*
914-915 MHz			*CT1*
915-925 MHz		FIXED	*Tactical radio relay* *GSM-R* (921-923 MHz) (Foreseen)
925-930 MHz		MOBILE except aeronautical mobile	*GSM*
930-932 MHz			*CT1+*
932-959 MHz			*GSM*
959-960 MHz			*CT1*
960-1215 MHz		AERONAUTICAL RADIONAVIGATION	Aeronautical surveillance DME *JTIDS/MIDS* *TACAN-DME*
1215-1240 MHz		RADIOLOCATION RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth)	*Defence systems* *Satellite navigation systems*
1240-1260 MHz		RADIOLOCATION RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) Amateur	Amateur *Defence systems*
1260-1270 MHz		RADIOLOCATION RADIONAVIGATION Amateur Amateur-Satellite	Aeronautical surveillance Amateur Amateur-satellite *Defence systems*
1270-1300 MHz		RADIOLOCATION RADIONAVIGATION Amateur	Aeronautical surveillance Amateur *Defence systems*
1300-1350 MHz		AERONAUTICAL RADIONAVIGATION Radiolocation	Aeronautical surveillance *Defence systems*
1350-1362.5 MHz		FIXED	Radio relay
1362.5-1375 MHz			*Defence systems*
1375-1387.5 MHz			Radio relay
1387.5-1400 MHz			*Defence systems*

1400-1427 MHz		RADIO ASTRONOMY	
1427-1439.5 MHz		FIXED	Radio relay
1439.5-1452 MHz			*Defence systems*
1452-1467.5 MHz		BROADCASTING	*T-DAB* (Foreseen)
1467.5-1492 MHz		BROADCASTING FIXED	Radio relay (No new assignments)
1492-1504.5 MHz		FIXED	Radio relay
1504.5-1517 MHz			*Defence systems*
1517-1525 MHz			*Defence systems* Radio relay
1525-1530 MHz		FIXED MOBILE-SATELLITE (space-to-Earth)	*Defence systems* MSS Earth stations
1530-1535 MHz		MOBILE-SATELLITE (space-to-Earth) Fixed	*Defence systems* MSS Earth stations
1535-1559 MHz		MOBILE-SATELLITE (space-to-Earth)	MSS Earth stations SAR (communications) (1544-1545 MHz)
1559-1610 MHz		AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth)	*Defence systems* *Satellite navigation systems*
1610-1613.8 MHz		AERONAUTICAL RADIONAVIGATION MOBILE-SATELLITE (Earth-to-space)	*Defence systems* *S-PCS*
1613.8-1626.5 MHz		AERONAUTICAL RADIONAVIGATION METEOROLOGICAL-SATELLITE (Earth-to-space) Meteorological-Satellite (space-to-Earth)	*Defence systems* *S-PCS*
1626.5-1660 MHz		MOBILE-SATELLITE (Earth-to-space)	MSS Earth stations SAR (communications) (1645.5-1646.5 MHz)
1660-1660.5 MHz		METEOROLOGICAL-SATELLITE (Earth-to-space) RADIO ASTRONOMY	*Defence systems* MSS Earth stations
1660.5-1668.4 MHz		RADIO ASTRONOMY	*Defence systems*
1668.4-1670 MHz		METEOROLOGICAL AIDS	*Defence systems*
1670-1675 MHz		METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE	*Defence systems* *Meteorology*
1675-1700 MHz		METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth)	*Defence systems* *Meteorology*
1700-1710 MHz		FIXED	
1710-1785 MHz		MOBILE	*GSM*
1785-1880 MHz			*Radio Microphones* (1785-1800 MHz) *GSM* (1805-1880 MHz)
1880-1900 MHz			*DECT*
1900-1980 MHz			*IMT-2000/UMTS*
1980-2010 MHz		FIXED MOBILE-SATELLITE (Earth-to-space)	*IMT-2000 satellite component* *S-PCS*

2010-2025 MHz		FIXED MOBILE	*IMT-2000/UMTS*
2025-2110 MHz		FIXED SPACE OPERATION (Earth-to-space) (space-to-space)	*Space Operations*
2110-2170 MHz		FIXED MOBILE	*IMT-2000/UMTS*
2170-2200 MHz		FIXED MOBILE-SATELLITE (space-to-Earth)	*IMT-2000 satellite component* *S-PCS*
2200-2290 MHz		FIXED SPACE OPERATION (space-to-Earth) (space-to-space)	*Space Operations*
2290-2300 MHz		FIXED	
2300-2450 MHz		MOBILE Amateur Radiolocation	Amateur SAP/SAB airborne video links *Defence systems* (2300-2400 MHz) *Detection of movement* (2400-2483.5 MHz) *ISM* (2400-2483.5 MHz) *Non-specific SRDs* (2400-2483.5 MHz) *Radio LANs* (2400-2483.5 MHz) Amateur-satellite (2400-2450 MHz) *AVI* (2446-2454 MHz) RFID (2446-2454 MHz) (Foreseen)
2450-2483.5 MHz		MOBILE Radiolocation	*Detection of movement* *ISM* *Non-specific SRDs* *Radio LANs* *AVI* (2446-2454 MHz) RFID (2446-2454 MHz) (Foreseen) *Defence systems* SAP/SAB airborne video links
2483.5-2500 MHz		FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) Radiolocation	Radio relay (No new assignments) *Radiolocation (military)* *S-PCS*
2500-2520 MHz		FIXED	Radio relay (No new assignments)
2520-2655 MHz		FIXED MOBILE except aeronautical mobile	Radio relay (No new assignments) SAP/SAB airborne video links
2655-2690 MHz		FIXED	Radio relay (No new assignments)
2690-2700 MHz		RADIO ASTRONOMY	
2700-2900 MHz		AERONAUTICAL RADIONAVIGATION Radiolocation	Aeronautical surveillance *Radiolocation (military)*
2900-3100 MHz		RADIONAVIGATION Radiolocation	*Radiolocation (military)*

3100-3400 MHz	RADIOLOCATION	*Radiolocation (military)*
3400-3450 MHz	FIXED Mobile Radiolocation	*Defence systems* SAP/SAB airborne video links (Envisaged)
3450-3500 MHz		Wireless Local Loop
3500-3550 MHz		*Defence systems* SAP/SAB airborne video links (Envisaged)
3550-3600 MHz		Wireless Local Loop
3600-4200 MHz	FIXED FIXED-SATELLITE (space-to-Earth)	FSS Earth stations Radio relay
4200-4400 MHz	AERONAUTICAL RADIONAVIGATION	
4400-5000 MHz	FIXED	*Defence systems*
5000-5150 MHz	AERONAUTICAL RADIONAVIGATION	MLS (5031-5091 MHz) (Envisaged)
5150-5250 MHz	AERONAUTICAL RADIONAVIGATION MOBILE	*HIPERLANs*
5250-5350 MHz	RADIOLOCATION	*HIPERLANs* *Defence systems*
5350-5470 MHz	AERONAUTICAL RADIONAVIGATION Radiolocation	*Defence systems*
5470-5650 MHz	MARITIME RADIONAVIGATION Radiolocation	*HIPERLANs* *Defence systems*
5650-5850 MHz	RADIOLOCATION	*HIPERLANs* (5470-5725 MHz) Amateur *Defence systems* Amateur-satellite (5650-5670 MHz) *ISM* (5725-5875 MHz) *Non-specific SRDs* (5725-5875 MHz) *RTTT* (5795-5815 MHz) Amateur-satellite (5830-5850 MHz)
5850-5925 MHz	FIXED	*ISM* (5725-5875 MHz) *Non-specific SRDs* (5725-5875 MHz)
5925-6425 MHz	FIXED FIXED-SATELLITE (Earth-to-space)	FSS Earth stations Radio relay (ERC/REC 14-01)
6425-6700 MHz		Radio relay (ERC/REC 14-02) SAP/SAB P to P video links
6700-7075 MHz	FIXED FIXED-SATELLITE (space-to-Earth) (Earth-to-space)	Radio relay (ERC/REC 14-02) SAP/SAB P to P video links
7075-7125 MHz	FIXED	Radio relay (ERC/REC 14-02) SAP/SAB P to P video links
7125-7250 MHz		Radio relay
7250-7300 MHz	FIXED FIXED-SATELLITE (space-to-Earth)	Radio relay *Satellite systems (military)* SAP/SAB P to P video links

		MOBILE-SATELLITE	(7280-7730 MHz)
7300-7450 MHz			Radio relay *Satellite systems (military)* SAP/SAB P to P video links
7450-7750 MHz		FIXED FIXED-SATELLITE (space-to-Earth)	Radio relay *Satellite systems (military)* SAP/SAB P to P video links (7280-7730 MHz)
7750-7900 MHz		FIXED	Radio relay
7900-8025 MHz		FIXED FIXED-SATELLITE (Earth-to-space) MOBILE-SATELLITE	*Satellite systems (military)*
8025-8400 MHz		FIXED FIXED-SATELLITE (Earth-to-space)	*Satellite systems (military)* *Fixed radio relay (military)* (8200-8500 MHz) Radio relay (8200-8500 MHz) (ITU-R F.386)
8400-8500 MHz		FIXED	*Fixed radio relay (military)* Radio relay (ITU-R F.386)
8500-8750 MHz		RADIOLOCATION	*Radiolocation (military)*
8750-8850 MHz		AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION RADIOLOCATION	*Radiolocation (military)*
8850-9000 MHz		MARITIME RADIONAVIGATION RADIOLOCATION	*Radiolocation (military)*
9000-9200 MHz		AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION Radiolocation	*Radiolocation (military)*
9200-9300 MHz		MARITIME RADIONAVIGATION RADIOLOCATION	*Radiolocation (military)* *Detection of movement*
9300-9500 MHz		RADIONAVIGATION Radiolocation	*Radiolocation (military)* *Detection of movement*
9500-9800 MHz		RADIOLOCATION RADIONAVIGATION	*Radiolocation (military)* *Detection of movement*
9800-10000 MHz		RADIOLOCATION Fixed Meteorological-Satellite	*Radiolocation (military)* *Detection of movement* (9500-9975 MHz)
10-10.15 GHz		RADIOLOCATION Amateur	*Radiolocation (military)* Amateur
10.15-10.3 GHz		FIXED RADIOLOCATION Amateur	*Radiolocation (military)* Amateur Wireless Local Loop
10.3-10.45 GHz		RADIOLOCATION Amateur	*Radiolocation (military)* Amateur
10.45-10.5 GHz		RADIOLOCATION Amateur Amateur-Satellite	*Radiolocation (military)* Amateur Amateur-satellite
10.5-10.55 GHz		FIXED Radiolocation	Wireless Local Loop *Detection of movement* Radiolocation (civil)
10.55-10.6 GHz		FIXED Radiolocation	Wireless Local Loop *Detection of movement*

			Radiolocation (civil) SAP/SAB P to P video links (10.56-10.588 GHz)
10.6-10.68 GHz		FIXED	Wireless Local Loop (10.5-10.65 GHz)
10.68-10.7 GHz		RADIO ASTRONOMY	
10.7-11.7 GHz		FIXED FIXED-SATELLITE (space-to-Earth) (Earth-to-space)	FSS Earth stations MSS Earth stations Radio relay (ERC/REC 12-06) SNG VSAT
11.7-12.5 GHz		BROADCASTING-SATELLITEFIXED	
12.5-12.75 GHz		FIXED-SATELLITE (space-to-Earth) (Earth-to-space)	MSS Earth stations SNG VSAT
12.75-13.25 GHz		FIXED	FSS Earth stations (No new assignments) Radio relay (ERC/REC 12-02) SAP/SAB P to P video links
13.25-13.4 GHz		AERONAUTICAL RADIONAVIGATION	
13.4-13.75 GHz		RADIOLOCATION	*Detection of movement* Radiolocation (civil) *Radiolocation (military)*
13.75-14 GHz		RADIOLOCATION	*Detection of movement* Radiolocation (civil) *Radiolocation (military)* FSS Earth stations
14-14.25 GHz		FIXED-SATELLITE (Earth-to-space) RADIONAVIGATION	FSS Earth stations SNG VSAT MSS Earth stations
14.25-14.5 GHz		FIXED-SATELLITE (Earth-to-space)	FSS Earth stations SNG VSAT
14.5-14.62 GHz			Radio relay (ERC/REC 12-07)
14.62-15.23 GHz		FIXED	*Fixed radio relay (military)*
15.23-15.35 GHz			Radio relay (ERC/REC 12-07)
15.35-15.4 GHz		RADIO ASTRONOMY	
15.4-15.7 GHz		AERONAUTICAL RADIONAVIGATION	
15.7-16.2 GHz		RADIOLOCATION	*Radiolocation (military)*
16.2-17.3 GHz			*Radiolocation (military)* *HIPERLANs* (17.1-17.3 GHz)
17.3-17.7 GHz		FIXED-SATELLITE (Earth-to-space) Radiolocation	*Radiolocation (military)*
17.7-19.7 GHz		FIXED	FSS Earth stations (No new assignments) Radio relay (ERC/REC 12-03)
19.7-20.2 GHz		not allocated	
20.2-21.2 GHz		FIXED-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth)	*Defence systems*
21.2-23.6 GHz		FIXED	Radio relay

			SAP/SAB P to P video links
23.6-24 GHz		not allocated	
24-24.05 GHz		AMATEUR AMATEUR-SATELLITE	*ISM* *Non-specific SRDs* Amateur Amateur-satellite
24.05-24.25 GHz		RADIOLOCATION Amateur	*ISM* *Non-specific SRDs* Amateur *Detection of movement* Radiolocation (civil) *Radiolocation (military)*
24.25-24.5 GHz		FIXED	
24.5-25.25 GHz			Radio relay (24.549-24.689 GHz) (ERC T/R 13-02) Wireless Local Loop (24.717-24.857 GHz) (ERC T/R 13-02) Radio relay (24.885-25.025 GHz) (ERC T/R 13-02) Wireless Local Loop (25.053-25.193 GHz) (ERC T/R 13-02) Radio relay (25.221-25.333 GHz) (ERC T/R 13-02)
25.25-25.333 GHz		FIXED MOBILE	Radio relay (ERC T/R 13-02)
25.333-25.5 GHz			*Fixed radio relay (military)* (25.333-25.445 GHz)
25.5-26.341 GHz			Radio relay (25.557-25.697 GHz) (ERC T/R 13-02) Wireless Local Loop (25.725-25.865 GHz) (ERC T/R 13-02) Radio relay (25.893-26.033 GHz) (ERC T/R 13-02) Wireless Local Loop (26.061-26.201 GHz) (ERC T/R 13-02) Radio relay (26.229-26.341 GHz) (ERC T/R 13-02)
26.341-27.5 GHz			*Fixed radio relay (military)* (26.341-26.453 GHz)
27.5-27.8285 GHz		FIXED	FSS Earth stations (27.5485-27.8285 GHz) (Foreseen)
27.8285-27.9405 GHz			*Fixed radio relay (military)* (Foreseen)
27.9405-28.8365 GHz			Radio relay (27.9405-28.1925 GHz) (Foreseen) Wireless Local Loop (28.2205-28.4445 GHz) (Foreseen) FSS Earth stations (28.5565-28.8365 GHz) (Foreseen)
28.8365-28.9485 GHz			*Fixed radio relay (military)* (Foreseen)
28.9485-29.5 GHz			Radio relay (28.9485-29.2005 GHz) (Foreseen)Wireless Local Loop (29.2285-29.4525 GHz)

			(Foreseen)
29.5-30 GHz		not allocated	
30-31 GHz		FIXED-SATELLITE (Earth-to-space) MOBILE-SATELLITE (Earth-to-space)	*Defence systems*
31-31.3 GHz		FIXED	
31.3-31.5 GHz		EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive)	
31.5-31.8 GHz		not allocated	
31.8-33.4 GHz		RADIONAVIGATION	Radio relay (Foreseen)
33.4-36 GHz		RADIOLOCATION	*Radiolocation (military)*
36-37.308 GHz		FIXED MOBILE	*Defence systems* (36-37 GHz) *Fixed radio relay (military)* (37.058-37.308 GHz) (ERC T/R 12-01)
37.308-37.5 GHz			Radio relay (ERC T/R 12-01)
37.5-38.318 GHz		FIXED	Radio relay (37.308-38.178 GHz) (ERC T/R 12-01)
38.318-38.568 GHz			*Fixed radio relay (military)* (ERC T/R 12-01)
38.568-39.5 GHz			Radio relay (38.568-39.438 GHz) (ERC T/R 12-01)
39.5-40.5 GHz		FIXED-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth)	*Satellite systems (military)* (Foreseen)
40.5-43.5 GHz		FIXED	MWS (Foreseen)
43.5-45.5 GHz		MOBILE MOBILE-SATELLITE RADIONAVIGATION RADIONAVIGATION-SATELLITE	
45.5-47 GHz		MOBILE MOBILE-SATELLITE RADIONAVIGATION RADIONAVIGATION-SATELLITE	
47-47.2 GHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
47.2-50.2 GHz		FIXED	HAPS (47.2-47.5 GHz) (Foreseen) HAPS (47.9-48.2 GHz) (Foreseen)
50.2-50.4 GHz		not allocated	
50.4-51.4 GHz		FIXED-SATELLITE (Earth-to-space) Mobile-Satellite (Earth-to-space)	
51.4-57 GHz		not allocated	
57-59 GHz		FIXED	Unplanned. uncoordinated fixed links (Foreseen)
59-62 GHz		MOBILE RADIOLOCATION	*ISM* (61-61.5 GHz)
62-64 GHz			*RTTT* (63-64 GHz)

64-66 GHz		not allocated	
66-71 GHz		RADIONAVIGATION RADIONAVIGATION-SATELLITE	
71-74 GHz		not allocated	
74-75.5 GHz			
75.5-76 GHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
76-81 GHz		RADIOLOCATION	Amateur Amateur-satellite *RTTT* (76-77 GHz)
81-84 GHz		not allocated	
84-92 GHz			
92-95 GHz		RADIOLOCATION	
95-100 GHz		RADIONAVIGATION RADIONAVIGATION-SATELLITE Radiolocation	
100-126 GHz		not allocated	*ISM* (122-123 GHz)
126-134 GHz		RADIOLOCATION	
134-142 GHz		RADIONAVIGATION RADIONAVIGATION-SATELLITE	
142-144 GHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
144-149 GHz		Amateur Amateur-Satellite	Amateur Amateur-satellite
149-190 GHz		not allocated	
190-200 GHz		RADIONAVIGATION RADIONAVIGATION-SATELLITE	
200-231 GHz		not allocated	
231-235 GHz		Radiolocation	
235-238 GHz		not allocated	
238-241 GHz		Radiolocation	
241-248 GHz		RADIOLOCATION Amateur Amateur-Satellite	Amateur Amateur-satellite *ISM* (244-246 GHz)
248-250 GHz		AMATEUR AMATEUR-SATELLITE	Amateur Amateur-satellite
250-252 GHz		not allocated	
252-265 GHz		RADIONAVIGATION RADIONAVIGATION-SATELLITE	
265-275 GHz		not allocated	