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Introduction

All radio systems share the same electromagnetic spectrum. This means that each radio receiver is detecting not just its wanted signal but all other signals transmitted at the same time anywhere – not just on this planet, but anywhere, even in space. If there are aliens out there using radio technology, their signals will also be added to the mix.

But it is rare for us to experience interference into our communication devices – such as radios, televisions and mobile phones – on a day-to-day basis. This is not an accident but the result of years of hard work by radio engineers and regulators to ensure that the signals from one user of the radio spectrum do not degrade significantly another user or, as is more commonly described, cause interference into the receiver.

Interference analysis is the study of how one or more radio systems can degrade the operation of other users of the radio system. It includes techniques to predict the level of interference and whether that could be tolerated or would represent a serious degradation, otherwise known as harmful interference.

This subject builds upon other specialist topics, such as antenna design and propagation, and often involves analysis of scenarios that includes different types of radio system. Therefore when undertaking interference analysis, it is necessary to become familiar with a wide range of other topics plus mathematical modelling techniques, statistics and geometry.

The objective of this book is to be useful to anyone involved in interference analysis – to help understand the various techniques and methodologies that could be used in studies. The approach in this book is to give an integrated view of interference analysis, describing all the key issues necessary to generate results. It will consider different types of interference and metrics to determine whether the interference could be accepted or would be considered harmful.

1.1 Motivations and Target Audience

There are different motivations for undertaking interference analysis, in particular:

- System design: to optimise a radio system to allow the maximum service while reducing interference, whether within the system, to other systems or from other systems
- Regulatory: to identify what radio services can share with other radio services and hence allow them to be included in the tables of allocation used by spectrum managers
- Frequency assignment: to determine if a regulator can issue a new licence (e.g. to a taxi company) without it causing or suffering harmful interference
- Coordination: during discussions between two radio system operators (or countries) to identify ways to protect each other's receivers from the other's transmissions.

This book is aimed at anyone with an interest in interference between radio systems, in particular those operating with frequency above about 30 MHz. This could include:

- A member of a national spectrum management regulator is meeting with representatives from a neighbouring country to make a bilateral agreement that can be used to protect each country from interference. What would be a suitable interference threshold level to agree and how would it be checked/calculated?
- A mobile operator's spectrum management team wants to open up new bands for next generation broadband. They need to argue at an international level, in particular at the International Telecommunication Union, that such an introduction would be the most effective use of the scarce radio spectrum.
- A satellite operator is meeting with another satellite operator to ensure that neither causes harmful interference into the other. At the coordination meeting they will agree the signal levels that can be transmitted on each satellite beam: what should they propose and how can they check the suggestions from the other company?
- A consultant is working for the aeronautical community to help identify bands that can be used to provide broadband services to commercial aircraft. They must undertake sharing scenarios and convince regional bodies, such as Europe and North America, that these will be safe.
- The national spectrum management regulator receives a request for a new licence to provide a service (e.g. land mobile or fixed link). How can they check it would not cause or suffer interference to/from existing licensees?
- Students studying electrical engineering, communication systems or simulation techniques, who wish to learn more about interference analysis and modelling radio systems, together with academics undertaking research on these topics.

1.2 Book Structure

The book is structured as follows:

Chapter 2. Motivations: considering the reasons why people undertake interference analysis, including the regulatory framework, international organisations and working methods.

Chapter 3. Fundamental Concepts: covers the basics of radio engineering, including modulations, access methods, antennas, noise calculations, the underlying geometry and dynamics, link budgets and their attributes.

Chapter 4. Propagation Models: the model of how radio waves propagate between transmitter and receiver (whether wanted or interfering) can make a huge difference to the results, so it is important to understand the various propagation models that are available and when they should be used.

Chapter 5. The Interference Calculation: how to use the concepts above to calculate interference, including aggregation effects, polarisation adjustment, co-frequency vs. non-co-frequency, thresholds, interference apportionment and possible mitigation techniques.

Chapter 6. Interference Analysis Methodologies: the complexity of the analysis can vary from static analysis, where the answer is a single number, to dynamic, Monte Carlo and area analysis, each with strengths and weaknesses. To help explain each of the different approaches, worked examples will show how they can be used to analyse sharing between:

- A deployment of base stations of a Long Term Evolution (LTE) network into satellite Earth stations in parts of C-band
- A non-GSO mobile-satellite service (MSS) system and point-to-point fixed links.

Chapter 7. Specific Algorithms and Services: some services and sharing scenarios have well-defined publically available algorithms to calculate performance including interference analysis. Examples would be broadcasting, private mobile radio, white space and satellite coordination.

1.3 Chapter Structure and Additional Resources

Each chapter is structured starting with a summary of its contents and ending with pointers for further reading. Within each chapter are examples of the calculations involved to, as far as possible, allow the reader to reproduce the analysis undertaken. There are also available additional resources to increase understanding of the topics being analysed. These include:

- Spreadsheets to support standard calculations, such as link budgets and geometry conversions
- Example simulation files configured for the scenario under discussion.

These can be found by following the link on the Wiley web site page for this book. Wherever possible the international system of units are used for all calculations.

1.4 Case Study: How to Observe Interference

It is generally hard to accidentally create interference between different types of consumer radio systems. It should be noted that deliberately causing interference into another's radio system is considered a criminal offence in most legal systems and so should not be attempted. But you could try observe the impact of interference into one of your own radio receivers in a licence exempt band and see if you can detect any change in behaviour.

A good frequency band to experiment with is the one used by Wi-Fi at around 2.4 GHz as this has a range of different uses including microwave ovens. These are shielded to reduce

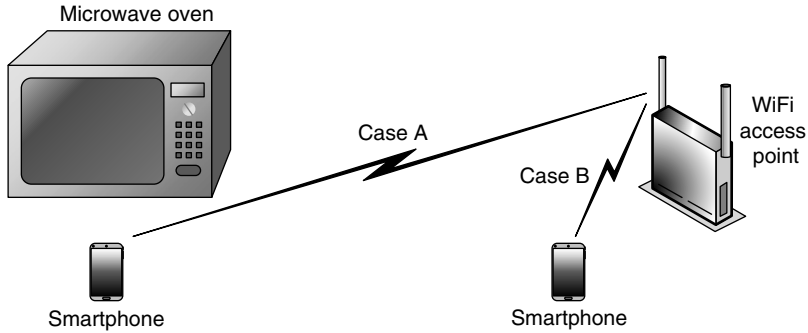


Figure 1.1 Domestic test set-up for detecting interference

Table 1.1 Results of tests for case A: Smartphone by microwave oven

Microwave oven	Off	On
Test 1	9.38 Mbps	0.72 Mbps
Test 2	9.40 Mbps	— ^a

^a The smartphone did not complete the speed test reporting ‘Network Communication Issues’.

Table 1.2 Results of tests for case B: Smartphone by Wi-Fi access point

Microwave oven	Off	On
Test 1	9.40 Mbps	7.24 Mbps
Test 2	9.38 Mbps	6.43 Mbps

emissions outside the device but there is usually some leakage that can be used as a source of interference into communications equipment. In particular, this can lead to issues for sensitive services such as radio astronomy. In 2015 the Parkes Radio Telescope in Australia investigated unusual signals it classed as ‘percytons’ and the source was discovered to be an on-site microwave oven emitting pulses at 1.4 and 2.4 GHz (Petroff et al., 2015).

For example, consider the two set-ups in Figure 1.1 where a smartphone was configured with an application to test the speed of the broadband link accessed via a Wi-Fi connection. Initially in case A the smartphone was positioned 0.5 m from a microwave oven and about 5 m from the access point. The Wi-Fi access point was configured to use the 2.4 GHz band rather than other frequencies (e.g. those around 5 GHz).

The throughput was tested twice for each of the cases when the oven is on or off with results as in Table 1.1.

In case B the smartphone was moved to be located 0.5 m from the access point and about 5 m from the microwave oven. The corresponding results are shown in Table 1.2.

From these tests the following results can be deduced:

- The microwave oven can degrade the performance of the smartphone’s communication link
- The degree of degradation varies depending upon the distances from the smartphone to the Wi-Fi access point and microwave oven.

You could try this yourself at home, though you are likely to get different numbers depending upon equipment types and broadband link. Note that no electronic device should be placed inside a microwave oven.

Note that while there was a degradation of the communication service from around 9.4 to 6–7 Mbps, this data rate could still be considered usable. One of the key questions about interference analysis is what counts as an acceptable level and what would be ‘harmful interference’.

This is an example of using measurement to detect how interference can degrade a communication service: the objective of this book is to describe tools and methodologies that can predict whether interference would or would not occur.

Important Note

All the systems and their parameters used in this book are for illustration purposes only. Any study based upon ideas in this book should check references, in particular for more recent developments.