RF 1090 MHZ BAND LOAD MODEL

Tomáš Lipták[1], Stanislav Pleninger[2]

Summary: Nowadays, the load of 1090 MHz frequency represents a key factor determining the quality of surveillance application in terms of air traffic control. Although there is an intention to provide more surveillance data on 1090 MHz, an uncontrolled access to the frequency is one of the aspects limiting to do so. In fact, with an increasing number of transmitted messages, the loss of information during the decoding on receipt is more probable due to the garbling or overlapping effect. Firstly, this text will discuss the use of the radio frequency of 1090 MHz with regard to the aeronautical traffic. Then, it will represent an approach to radio frequency load measurement using computer based modelling. Finally, model RFLM 2014 that was created will be described in a greater detail together with results for a FIR of the Czech Republic.

Key words: Radio frequency load, 1090 MHz, transmission modelling, surveillance system, transponders, DF messages, Mode S, Mode A/C, ADS-B, Extended Squitter

INTRODUCTION

With an increase in the aeronautical traffic, it is becoming considerably important to address the need for implementation of sufficient surveillance technologies. In order to keep a certain level of safety through the traffic awareness, various flight data are measured aboard and then transmitted in pre-defined message formats on the radio-frequency of 1090 MHz. However, the measurement of the flight data as such is not as problematic as their effective distribution to the receiver. Due to an uncoordinated access of Mode A/C/S transponders, TCAS and ADS-B units to the RF band increase a probability of message loss or garbling and thereby the unsuccessful decoding on reception. The loss of the messages may adversely affect the surveillance system. For example, the ADS-B information is updated and transmitted periodically. If the frequency is overloaded, the information may be received and updated on the reception in longer periods which may not be sufficient with regard to surveillance requirements. Likewise, as far as secondary surveillance radars are concerned the so-called re interrogation rate will likely be increased causing even greater load of the RF band. This vicious circle will have an adverse impact on the performance reliability of all devices working on 1090 MHz. On the one hand, it is inevitable to transmit a greater amount of information among the increasing number of the aircraft and surveillance systems. On the other, this is technically limited with regard to the maximum number of messages that can be trans-mitted on the frequency and still be reliably decoded. Therefore, a load of 1090 MHz

[1] Bc. Tomáš Lipták, Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Air Transport, Horská 3, 128 03 Prague 2, Tel.: +420 773 260 636, E-mail: liptatom@fd.cvut.cz

[2] Ing. Stanislav Pleninger, Ph.D., Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Air Transport, Horská 3, 128 03 Prague 2,, Tel.: +420 224 359 185, E-mail: pleninger@fd.cvut.cz

band is becoming particularly important especially with respect to the future air traffic. Computer models may be used as effective tools for evaluation of how the current and new technologies may affect the load of 1090 MHz.

1. MODELLING CHALLENGE

1.1 RF Load measurement

Many national and international organizations have focused on the load of 1090 frequency band. As mentioned above, it is inevitable to provide a greater amount of information so as to maintain the quality and desirable surveillance service. However, as far as the future scenarios are considered, the RF channel overloading will likely lead to considerable difficulties. Therefore, there is an effort to effectively measure and describe the frequency load in order to provide data for further research in this field.

In general, there are two approaches to estimate the frequency load. It is either a real measurement or computer modelling. Regarding the high complexity arising from many radio systems interactions, the mathematical models usually deal with programming difficulties in the beginning in contrast to the real measurement. Nevertheless, computer simulation may be a suitable tool for estimating the load depending on the environment parameters. Hence, it may be used for the future RF band load forecasts. Moreover, such models enable to study the load from more perspectives and they can also cover overlapped messages that may be neglected in the real measurement.

Various models were developed in the UK or Germany for their national needs. Likewise, Helios company created a model for Eurocontrol.

1.2 Simulation-based Approach

In the past 30 years, several computer models have been developed. Using different approaches, they were mainly created to forecast the load of the frequency 1090 MHz.

British SIEM – SSR/IFF Environment Model – has its origins in 1980s. It comprised of several programs that could be used separately and each of them, in fact, estimated the frequency load with respect to each device/technology. The reason behind this was mainly to lower the requirements on computers. The program genera-ted an environment based on the input values. When interrogation spectrum on 1030 MHz was estimated, the probable behavior of on-board devices and thus their transmission on 1090 MHz was calculated (1). The program also respected the probability of device unavailability caused by processing another interrogation. The result was represented as a map with contours connecting the points with the same rate of messages sent on 1090 MHz. The National Air Traffic Services provided real data that were used to verify the SIEM model in 1986 (1).

A German company ESG Elektronik System- und Logistik GmbH developed so-called SISSIM standing for SSR/IFF System Simulation. The program was used not only by the national air traffic services in Germany but also by the Ministry of Defence (2). It was based on time discrete simulation of both 1030/1090 MHz transmissions. Its approach stressed a combination of simulation techniques together with real environment measurements. Furthermore, it was designed to be used in the civil as well as military field. Similarly to the previously described model, the program cove-red the probability of device unavailability. Also, the reception quality factor, decryption quality, or multipath signal propagation were considered too (2).

Likewise, Eurocontrol has developed a simulation tool in cooperation with the Helios Company, called Mode S Simulator, to forecast the load of 1090 MHz. The key features that were required were following (3):

- provide results to illustrate an impact of the use of various SSR interrogating modes and characteristics, and an impact of the new devices working on 1030/1090 MHz
- simple modification of the program code if needed

Regarding the requirements (primarily the necessity of ad hoc modification), the Visual Basic environment was chosen as a default platform. The Mode S Simulator was launched in 2003 providing following functions relevant to the research goals of Eurocontrol.

- Impact of Mode A/C, Mode S, TCAS and ADS-B usage on 1090 MHz
- Adjustable parameters of TCAS
- Impact of the terrain on the electromagnetic wave propagation
- Adjustable power parameters of transmitters and adjustable sensitivity parameters of receivers
- Optional parameters of terrestrial receivers of each sector

Although the program provided estimation of the 1090 MHz, Eurocontrol stated additional requirements so as to precise the results obtained. It is, for example, a calculation of transponder’s availability, defining the radar coverage by means of radar coverage maps, or continuous calibration through the real measurements (3).

2. RFLM 2014 (RF LOAD MODEL 2014)

The simulation uses a mathematical approach to estimate the load of 1090 MHz band. Based primarily on a MATLAB platform, the model generates transmissions on the frequency band within a user-specified virtual environment according to technical specifications and current aviation regulations. Subsequently, the interactions and transmission triggers among radars, and Mode A/C/S transponders, TCAS and ADS B units on 1030/1090 MHz are described within mathematical conditions. Understanding of triggers for transmitting on 1090 MHz allows to calculate a total number of messages broadcasted over an area that is specified by receiver parameter. The model may thus likely be employed for an evaluation of various surveillance systems and future scenarios.

Final numerical results refer to how many messages were sent per second in an area covered by a particular receiver. It is stated, in addition, with regard to the message downlink format.

Model Inputs:

- Dimensional specification of simulation environment,

- Aircraft density in an elementary volume,
- Distribution of ground speeds, flight levels, equipment in the overall set of the aircraft,
- Parameters of secondary surveillance radars,
- Parameters of virtual receivers.

Model Results:
- Number of Downlink Messages received per second on virtual receivers,
- Message Format recognition: Mode A/C, DF11, DF4/5/20/21, DF0/16, DF17.

Each type of interaction is associated with a particular message downlink format (DF). Therefore, based on the environment that is studied, different types of message spectrum may be obtained. The model allows to count a number of messages with regard to their format. The result then characterizes a specific area within the model environment within virtual receiver's coverage. In contrast to real measurement, this solution covers even the messages that arrive at the receiver at the same time and which would be hardly decoded in the real measurement. Hence, the model approach may be beneficial since no data are lost comparing to the real measurements. Moreover, the model may have an advantage of providing data to illustrate and assess the impacts of each technology separately if needed.

2.1 Environment

Before the program is launched, the essential input data determining the environment have to be set by user in an input file. The simulation environment is defined in terms of limiting longitudes and latitudes, and setting volumetric density of the air-craft. Vertical dimension is divided into 3 vertical bands (low, medium, high). Relevant parameters are used to describe the maximum and minimum altitude at which the aircraft may fly within a particular vertical band. Properties of each vertical band are average ground speed, flight level separation and proportional usage. Next, a proportional distribution of the on-board equipment has to be also defined. In this case, there are four options (Tab. 1):

Tab. 1 - On-board Equipment Options

Equipment ID	Function 1		Function 2	Function 3
1	Mode A/C transponder		N/A	N/A
2	Mode S transponder		N/A	N/A
3	Mode S transponder		ACAS	N/A
4	Mode S Transponder		ACAS	ADS-B

Source: Authors

Furthermore, the environment also includes secondary surveillance radars. Apart from the coordinates, altitude above the sea level (AMSL) and coverage, more details to characterize radar interrogation patterns need to be set. They are following: width of the main beam, revolutions per minute, interrogating periods for BDS registers, for example.

Understanding of radar interrogation patterns on 1030 MHz and its overall characteristics is inevitable for the 1090 MHz transmission estimation. Likewise, receivers, that enables virtual measurement in the simulation, need to be set.

2.2 Transmission Estimation

When the program is launched, it initially calculates number of aircraft over the specified area based on the aircraft density parameter. Then, coordinates are assigned to each aircraft applying uniform probability distribution. Similarly, the altitude is added together with the heading and ground speed. However, the conditions of the particular vertical band are respected. Finally, the on-board equipment is set for each aircraft regarding the equipment distribution parameter only.

Next, the program simulates the flight of the aircraft over the time period that is set. During this, it calculates interactions of the aircraft with the radars, other aircraft and it also covers automatic transmission of the squitters. Whereas in terms of radars, the amount of solicited messages sent on 1090 MHz is primarily given by the parameters of the each radar and time spent in the coverage, the number of replies to ACAS interrogations differs with respect to relative positions, headings and speeds of the two aircraft. In addition, it depends on the aircraft-intruder equipment. The model recognizes interactions with Mode A/C or Mode S transponder, or ADS B unit where hybrid surveillance is used. In this part where ACAS is simulated is a Closest Point of Approach (CPA) time considered.

While calculating the transmission within the specified environment, the message type is concerned. Finally, the model provides results describing the load of the RF 1090 MHz. The result is obtained by using virtual receivers by which the frequency load is monitored. Then, the amount of messages sent per second depends on number of aircraft in the receivers range. The message downlink format is respected.

2.3 Results generated for FIR of the Czech Republic

Tab. 2 - Basic Environment Parameters

Density of Aircraft	3.78 x 10-3 in volume element 5NM x 5NM x 1000 ft
LAT1/LAT2	43° N / 60° N.
LON1/LON2	5° E / 24° E
Number of SSRs	83

Source: Authors

Tab. 3 - On-board Technology Distribution

Only Transponder Mode A/C	Only Transponder Mode S	Transponder Mode S + ACAS	Transponder Mode S + ACAS + ADS-B
5%	10%	50%	35 %

Source: Authors

Tab. 4 - Vertical Dimension Parameters

Vertical Band	Low	Medium	High
Minimum Band FL [1]	60	150	290
Maximum Band FL [1]	150	290	400
Flight Level Separation [1000ft]	1	1	2
Usage proportion [%]	30	20	50
Ground Speed [kts]	270	400	486

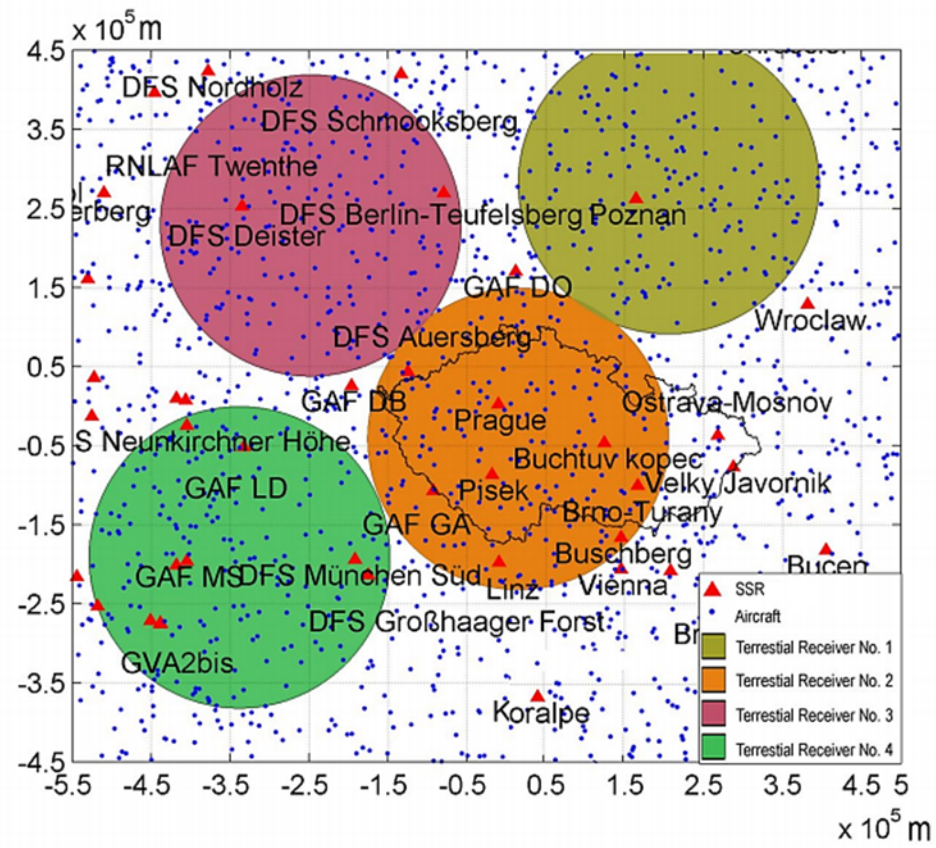
Source: Authors

Tab. 5 - Numerical Result Summary

Receive No.	Number of Aircraft in receiver‘s coverage	Mode A/C format [Hz]	DF11 [Hz]	DF4/5/20/21 [Hz]	DF17 [Hz]	DF0/16 [Hz]
1	199	45.637	126.309	669.105	324.367	451.287
2	186	43.828	108.418	1577.642	369.991	409.277
3	190	41.519	107.032	1627.485	376.260	451.940
4	181	59.128	102.494	1811.413	361.445	389.122

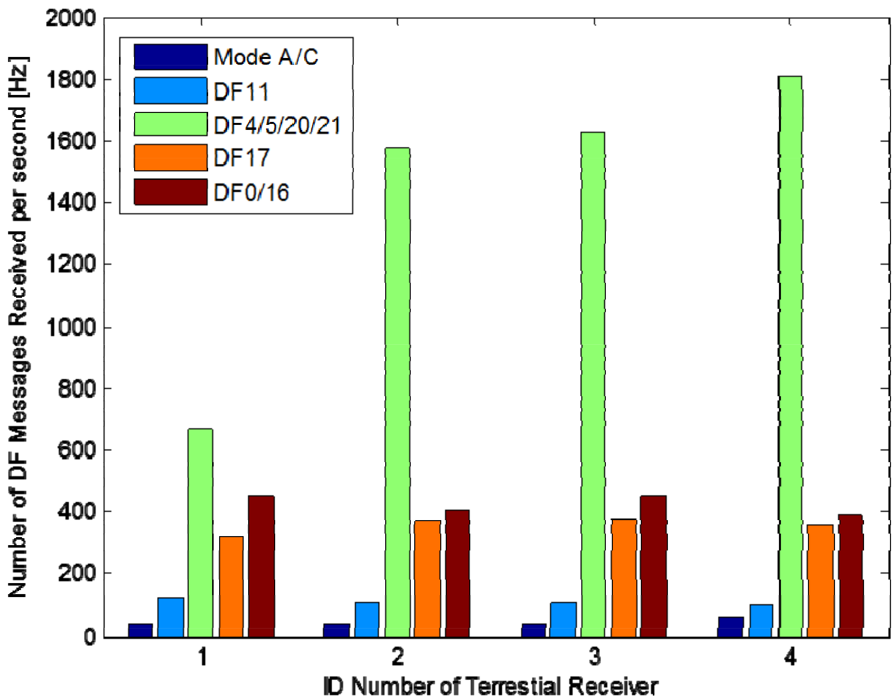
Source: Authors

Total Number of Aircraft: 3, 721
Simulated time period: 30 s



Source: Authors

Fig. 1 - Simulation Environment Review



Source: Authors

Fig. 2 - Result of 1090 MHz Frequency Load

CONCLUSION

An employment of transponder-based technologies for current surveillance purposes poses particularly cost-effective solution allowing further development while still using 1090 MHz. Although sharing the frequency by several technologies without coordination is technically beneficial, the drawbacks arising from more frequent garbling and overlapping on reception are evident in dense air traffic. This inevitably leads to deteriorated surveillance conditions as the probability of successful information exchange decreases. Since there is an effort to transmit even greater amount of information in the future, the models may represent an effective and only tool to estimate the load of 1090 MHz together with the impact of each technology.

This text discussed the use of the computer-based approach to measurement of the frequency load. Also the qualities of three computer models simulating 1090 MHz transmission successfully used in Europe were summarized. Our model RFLM 2014, which was introduced together with results related to FIR of the Czech Republic, showed also a considerable input sensitivity. Therefore, it is desirable to consider an effect of possibly incorrect input data that may be misleading for further calibration in the future. Likewise, additional modules dealing, for example, with SSR re-interrogate patterns, may improve the result accuracy. The model may be used not only for total load estimation but also for other research activities where the knowledge of DF message spectrum is needed.

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