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Correlations between the Interference Statistics of Finnish Radio Systems and EMC Market Surveillance In Finland

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ABSTRACT

In this paper two sets of interference statistics have been compared against those of the EMC market surveillance statistics made by The Safety Technology Authority (TUKES). The main focus has been on electrical equipment. The aim of the paper is to find out whether there is a potential use and usefulness for the applying of interference statistics when evaluating the effectiveness of EMC market surveillance, and also when in allocating EMC market surveillance resources. Also, the costs of EMC market surveillance have been compared against the costs of interference problem resolving.

1 THE INTERFERENCE STATISTICS FOR RADIO SYSTEMS IN FINLAND

This section contains statistics relating to identified interferences in radio systems, which have been recorded in Finland. These statistics have been collated by two different bodies; one an authority and the other corporate. The statistics are examined more carefully in those cases where the cause of interference was in electrical equipment.

1.1 The Finnish Communications Regulatory Authority

The Finnish Communications Regulatory Authority (FICORA) [1] usually identifies and clarifies reported radio interference cases. In addition, it also carries out active surveillance. Reports on problems are usually the basis for when measures are taken to correct any interference in radio communications.

In addition to the Helsinki based Radio Monitoring Centre, FICORA has three radio monitoring stations around Finland. The monitoring of radio communications and the clarification of radio interference is carried out at the centre and the stations.

Frequency planning and radio monitoring centre personnel co-operate when clarifying radio interference. Experience gained from solving interference problems is, in turn, utilized both in frequency planning and in evaluating the need for change in technical requirements.

The equipment market is monitored in order to ensure that consumers get only radio and telecommunications terminal equipment that complies with requirements and that is suitable for use in connection with other types of radio and telecommunications equipment. Equipment that does not meet requirements can be disturbed by outside sources or cause interference in radio and telecommunications.

1.1.1 Interference statistics

Between the years 1991 and 2000, FICORA registered 3,723 cases of interference to radio systems. Fig. 1 shows the proportion of different interference sources. 603 (16 %) of interference cases were found to have been caused by electrical equipment. The annual make up of these cases is shown in chapter 1.3. [2]

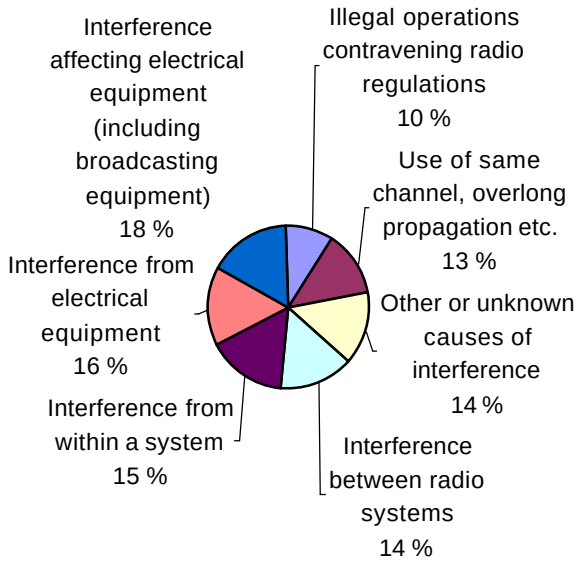

Fig.1. FICORA's Interference Statistics 1991-2000, Proportion of Different Sources

FICORA has divided statistics into three categories with regard to interferences caused by electrical equipment: information technology (IT), industrial, scientific and medical radio-frequency equipment (ISM) and Others. ISM equipment is identified according to a specific CISPR standard [3]. The distribution of these categories is shown in Fig. 2. The same groupings have been applied throughout this paper.

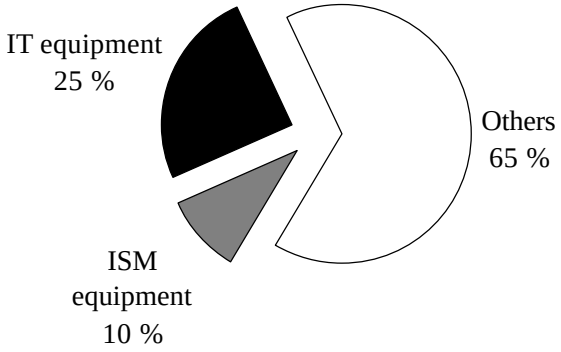

Fig.2. FICORA's Interference Statistics 1991-2000, Interferences Caused by Electrical Equipment

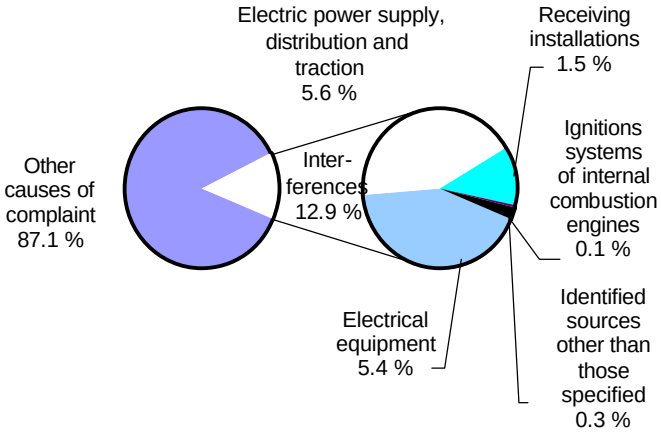

Fig. 3. Digita Oy's Classification of Sources of Interference and Other Causes of Complaint 1991-2000

1.1.2 Costs of Radio Monitoring

Between 1992-2001, the costs of radio monitoring equipment (measuring equipment and monitoring vehicles) have been € 968,832. In future, annual measuring equipment investment costs will be about € 100,000; this sum will double some years if any special equipment has to be purchased. 95 % of the usage time of measuring equipment is used for the monitoring of radio communications and radio interference problem solving. 5 % is used for market surveillance purposes.

In 2000, FICORA's radio monitoring personel costs amounted to € 993,378. Of this sum, 15 % went to the monitoring of radio communications, 68 % to the clarification of radio interference, and 17 % to market surveillance. About 2 % of FICORA's market surveillance is EMC related and about 98 % is related to the RTTE-Directive.

1.2 Digita Oy

Digita Oy [4] is the sole nation-wide broadcasting company responsible for radio and television broadcasting in Finland. Digita Oy gives information to the public when television and radio transmissions are not seen or heard normally or there are interferences. When necessary, their experts give advice in matters relating to e.g. the technique of antennas, digital television and digital radio.

1.2.1 Interference statistics

According to Digita Oy's statistics on radio systems [5] there were 13,293 recorded interference and other causes of complaint between the years 1991-2000. In Fig. 3, these cases are divided pursuant to the source of interference or other causes of complaint. It should be taken into consideration that these numbers represent cases which have required a site visit. Digita Oy's intention is, if possible, to solve cases by phone.

Within the class, *Other Causes of Complaint*, inefficient aerial installations were the reason for 3,322 cases (29 % of cases within the class, 25 % of all cases), tree stands and hills accounted for 2,727 cases (24 % of cases within the class, 21 % of all cases) and faults in connecting wire, amplifier, spur network, etc. 1,170 cases (10 % of cases within the class, 9 % of all cases).

Within the class, *Electric Power Supply, Distribution and Traction,* the main sources of interference were insulators of 1-100 kV overhead power lines (339 cases, 45 % of cases within the class, 2.4 % of all cases) and poor contact at hardware of 1-100 kV overhead power lines (314 cases, 42 % of cases within the class, 2.3 % of all cases).

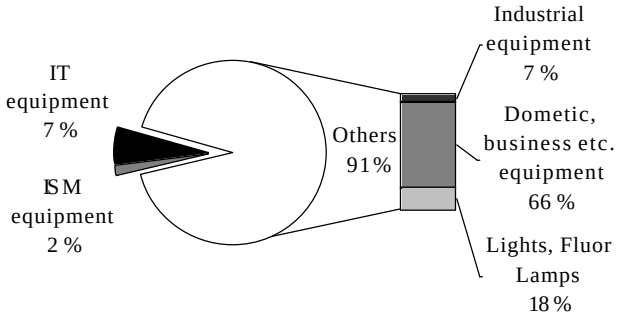

Fig. 4. Digita Oy's Interference Statistics 1991-2000, Interferences Caused by Electrical Equipment

722 (5.4 %) of all interference and complaint cases were caused by electrical equipment. Cases relating to electrical equipment have been defined in Fig. 4 and in Table 1. The annual make up of these cases is shown in chapter 1.3.

Table 1. Disturbing Electrical Equipment

Equipment group	Observations	%	%
IT equipment	***48***	***100***	***6.6***
Data processing equipment	37	77	5.1
Telephone exchanges and other digital telecommunication equipment	8	17	1.1
Local area networks	2	4	0.3
Commercial video games	1	2	0.1
ISM equipment	***12***	***100***	***1.6***
Industrial and scientific RF apparatus	8	67	1.1
Sparking apparatus (except ignition)	3	25	0.4
Medical RF apparatus	1	8	0.1
Industrial equipment	***51***	***100***	***7.1***
Cattle fences	11	21	1.5
Motors	5	10	0.7
Chargeable lighting units	5	10	0.7
Rectifiers	4	8	0.6
Convertors	3	6	0.4
Diode, thyristor and thyratron control equipment	3	6	0.4
Contact devices	2	4	0.3
Other installations	18	35	2.5
Domestic, business etc. equipment	***482***	***100***	***66.8***
Thermostats	393	82	54.4
Motors	50	10	6.9
Other contact devices other than thermostats	32	7	4.5
Diode, thyristor and thyratron control equipment	7	1	1.0
Lighting equipment	***129***	***100***	***17.9***
Faulty lighting	75	58	10.4
Filament lamps	46	36	6.4
Neon signs	5	4	0.7
Fluorescent	3	2	0.4
TOTAL	***722***		***100***

1.2.2 Costs of Interference Resolving

It has not been possible to gain information relating to Digita Oy's interference problem solving costs.

1.3 An annual make up of interference cases

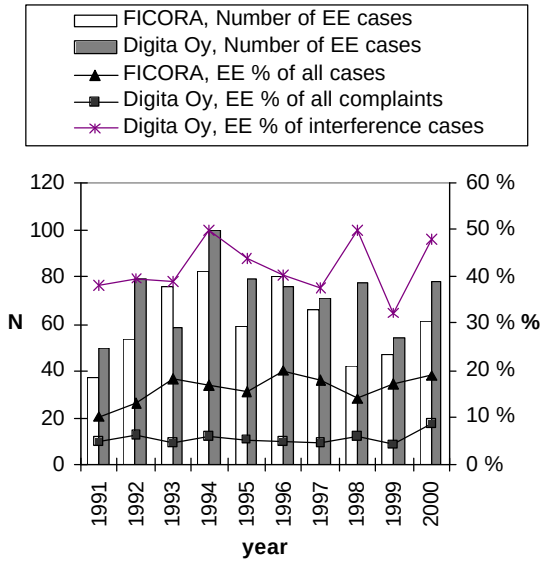

Fig. 5. An Annual Make up of Interference Cases Caused by Electrical Equipment

Fig. 5 shows the annual make up of interference cases caused by electrical products and recorded by FICORA and Digita Oy. The same figure shows the proportion of interference cases caused by electrical products out of all interference cases, and in Digita Oy's case, the proportion out of all causes of complaint, too.

2 THE EMC MARKET SURVEILLANCE OF ELECTRICAL EQUIPMENT IN FINLAND

In Finland, market surveillance for electrical equipment has been carried out since 1994 through testing products available on the market. Up to the year 2000, about 6,600 products had been tested. Tested products were very often suspected of having shortcomings with regard to technical requirements. The tests have mainly taken the form of safety tests. More information on Finnish market surveillance for electrical equipment can be found, for example, in [6, 7, 8].

2.1 TUKES's EMC Market Surveillance Statistics

During the period 1994-2000, 296 products were selected for EMC testing (4.5 % of all tested products). Between the years 1994 and 1996, EMC market surveillance sought clear methods for itself. From 1997, about 65 products have been EMC tested annually.

Table 2. EMC Tested Products and Findings

Equipment group	Satisfactory	Shortcomings	Measures	Total
IT equipment	***6***	***18***	***16***	***24***
Data processing equipment	2	18	16	24
ISM equipment	***10***	***8***	***5***	***18***
Frequency converters	10	8	5	18
Industrial equipment	***0***	***0***	***0***	***0***
Domestic, business etc. equipment	***123***	***101***	***32***	***224***
Battery chargers	4	1	1	5
Kitchen utensils	24	7	4	31
Heaters	1	1	0	2
Massage equipment	3	7	3	10
Blow-driers	17	10	1	27
Hairdressing equipment	7	2	0	9
Electric tools	7	10	4	17
Hot air fans	2	5	2	7
Garden tools	3	1	1	4
Sewing machines	2	0	0	2
Orchestra amplifiers	23	6	2	29
Vacuum cleaners	4	6	1	10
Cattle fences	1	1	1	2
Uninterruptible power systems	6	11	5	17
Inverters, converters	1	9	4	10
Connectors	3	2	1	5
Others	15	22	2	37
Lighting equipment	***19***	***11***	***3***	***30***
Self ballasted lamps	10	6	3	16
Other lamps	8	1	0	9
Other lighting equipment	1	4	0	5
TOTAL	*157*	*139*	*56*	*296*

Very often during the course of the visual examination of a product selected for safety testing, the possible need for EMC testing has also been identified. In these cases, the test laboratory proposes EMC testing of the product and TUKES decides on the needs for tests. About three-quarters of EMC tested products are selected in this way. About one quarter of all EMC tests are initiated by TUKES.

The distribution of EMC tested products is shown in Table 2 and Fig 6. Groupings in this section have been made according to the EMC emission standard, which is mentioned in Manufacturers' Declaration of Conformity document. The groupings are made following: ISM equipment ~ [3], IT equipment ~ [9], Lighting equipment ~ [10], Industrial equipment ~ [11], Domestic ~ the rest (mainly [12]).

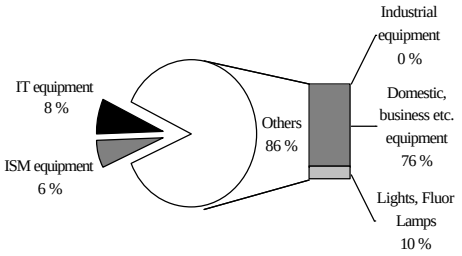

Fig. 6. TUKES's EMC Market Surveillance 1994-2000, All Tested Products (n=296)

From the tests, 139 (47 %) of products had shortcomings identified.

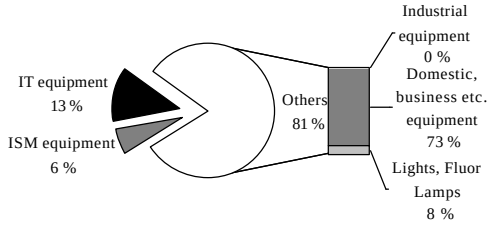

Fig. 7. TUKES's EMC Market Surveillance 1994-2000, Shortcomings Identified (n=139)

Out of 139 instances, 56 cases led to various measures being taken. The next diagram shows the percentages of TUKES measures in product categories.

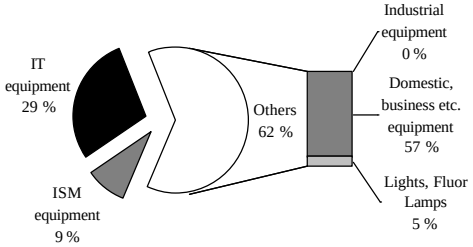

Fig. 8. TUKES's EMC Market Surveillance 1994-2000, Measures Being Taken (n=56)

2.2 Costs of EMC Market Surveillance

The costs of market surveillance tests can be seen from Table 3.

Table 3. Costs of Market Surveillance Tests for Electrical Products, 1994-2000

Item of expenditure	**€**
Purchasing costs of tested equipment	***673,044***
Safety tests made on the equipment	576,022
Both safety and EMC tests made on the equipment	45,816
EMC tests made on the equipment	14,078
No test	37,127
Test costs	***7,049,565***
Safety tests	6,789,878
EMC tests	259,686
TOTAL	***7,722,609***

In 2000, EMC market surveillance test costs were € 31,346 and the purchasing costs of EMC tested equipment were € 13,957. TUKES's staff costs per employee were € 40,191. EMC market surveillance was carried out by one full-time employee, furthermore six employees spent about 10 % of their working time on EMC market surveillance. So, the total cost of EMC market surveillance was about € 110,000 in the year 2000.

3 STATISTICAL METHODS

Comparisons between different distributions have been made by using the chi-square test for equality of distributions [13], [14]:

$$\chi^2 = \sum_{i=1}^{k} [(o_i - e_i)^2 / e_i] \qquad (1)$$

where k = number of data points
o_i = observed counts
e_i = expected counts.

After the chi-square value has been calculated, the level of significance associated with chi-square test (a.k.a. probability) has been looked up in a specific table [15].

4 COMPARISONS AND CORRELATIONS

Fig. 9 shows the number of cases which different instances registered during the period 1997-2000. The numbers of interference cases caused by electrical equipment in both sets of interference statistics are at the same level. In addition, the number of products selected for EMC market surveillance testing seems to have the same order of magnitude.

Table 4. The Chi-Square Test between FICORA's Interference Statistics and TUKES's EMC Market Surveillance Measures

Product Category	FICORA's Interference Cases	Ratio	Obs. (TUKES's Measures)	Exp. (Obs.*Ratio)	Obs.-Exp.	$(Obs.-Exp.)^2$	$(Obs.-Exp.)^2/Exp.$
ISM	61	0.101161	5	5.665008	-0.665008	0.442236	0.078064
IT	148	0.245439	16	13.74461	2.25539	5.086783	0.370093
Others	394	0.6534	35	36.59038	-1.590381	2.529313	0.069125
Total	603	1.00000	56				**0.517282**

Table 5. In the Chi-Square Test between Digita's Interference Statistics and TUKES's EMC Market Surveillance Cases, Industrial Equipment is Transfered into the ISM Category

Product Category	Digita's Interference Cases	Ratio	Obs. (TUKES's Cases)	Exp. (Obs.*Ratio)	Obs.-Exp.	$(Obs.-Exp.)^2$	$(Obs.-Exp.)^2/Exp.$
ISM	63	0.087258	18	25.82825	-7.828255	61.28157	2.372656
IT	48	0.066482	23	19.67867	3.32133	11.03123	0.560568
Others	611	0.84626	255	250.4931	4.506925	20.31237	0.08109
Total	722	1.00000	296				**3.014314**

When different statistics are compared to each other, it can be noticed that FICORA's interference statistics (Fig. 2) and TUKES's EMC market surveillance measures (Fig. 8) are statistically equally distributed within these categories of electrical equipment. In Table 4, comparing the latter to the first one gives a chi-square-value of 0.52. The level of significance associated with a chi-square test can now be looked up in a table in [15] using *the degrees of freedom* value of 2. That gives the probalility of 0.77.

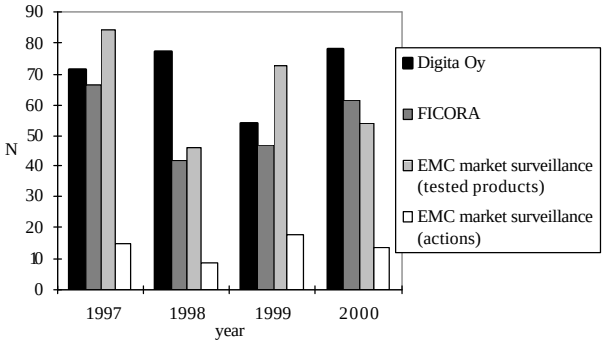

Fig 9. Number of Cases in Statistics 1997-2000

Comparisons between Digita Oy's statistics and those of other involved bodies show no statistical similarities.

Still one has to note that some correlation between Digita Oy's statistics and the products selected for EMC market surveillance testing (Fig. 6) can be seen when industrial equipment is moved into the ISM category, as in Fig. 10 and Table 5. Then the chi-square-value is 3.01, which gives the probability of 0.22.

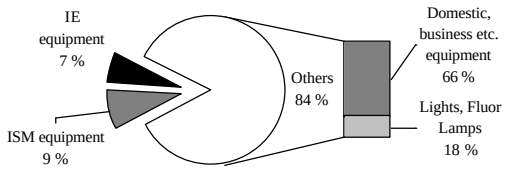

Fig. 10. In Digita Oy's Interference Statistics 1991-2000,Interferences Caused by Electrical Equipment, Industrial Equipment has been Transfered into the ISM Category

The purpose of EMC market surveillance is to prevent electromagnetic disturbances. In 2000, FICORA's costs relating to the clarification of radio interference were about € 768,000, which was somewhere seven times bigger than TUKES's EMC market surveillance costs. Furthermore, radio interference problem solving had caused noteable costs, at least, to Digita Oy.

5 SOURCES OF ERROR

It should be taken into consideration that the basis of groupings in the interference statistics is different from those of EMC market surveillance statistics. Digita Oy's statistics are based on classifications made by CISPR. FICORA has created their own classification system, which best serves their interests. Whereas

TUKES's groupings are based on the scopes of IEC's and CENELEC's EMC standards. For example, cattle fences belong to the *industrial*-category in CISPR's classification although they come under the scope of [12]. Under the circumstances, Digita Oy's 11 cattle fence cases belongs to the *industrial equipment* - category, whereas in TUKES's cases, both cattle fence cases fall under the *domestic*–category.

TUKES's EMC market surveillance has been closely combined with the safety surveillance of electrical equipment. For this reason, EMC related costs cannot be accurately specified separately from the total market surveillance costs of electrical equipment.

It should be noted that market surveillance should only be directed towards new equipment and should not cover equipment which has failed when in use. To this effect, Digita Oy's disturbance cases in thermostats do include mostly that type of equipment which has failed under use.

6 CONCLUSIONS

The number of EMC market surveillance tests since 1997 has been about same as the number of recorded interference cases. In future, it would be worthwhile for TUKES to consider the developing trend of interference cases when planning for the volume of EMC market surveillance testing, e.g. budgeting, etc. The annual costs of EMC market surveillance are, however, considerably lower than the costs of radio interference problem solving.

When comparing interference statistics and EMC market surveillance figures, two main conclusions can be drawn:

1) The products TUKES selected for EMC market surveillance tests represented the same product categories, which caused interference to radio and TV broadcasting.
2) The complaints FICORA received concerning interfering electrical equipment, correspond surprisingly well to the equipment groups, which have received the majority of EMC market surveillance measures.

To date, TUKES has not applied Digita Oy's classification of sources of interference and other causes of complaint when allocating EMC market surveillance. Still, some similarities between allocations can be seen. One might conclude from the comparison of statistics, that TUKES has succeeded in selecting EMC tested products with the intention of removing non-compliant products from the market. In future, Digita Oy's detailed classification of sources of interference is worth making good use of when applying EMC market surveillance resources.

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