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APPLICATION OF A NEW TERRESTRIAL TELECOMMUNICATIONS SYSTEM IN THE EUROPEAN AIR TRAFFIC

SUMMARY

Aeronautical Public Correspondence (APC) is a telecommunications service, which enables passengers onboard aircraft to make telecommunication calls to people on the ground.

This article describes the terrestrial communications service which is based on cellular network for the European CEPT member countries (CEPT – European Conference of Postal and Telecommunications Administrations) named Terrestrial Flight Telecommunications System (TFTS).

This system is a Pan-European System, which means the usage of harmonised frequencies in Europe with harmonised standards for the TFTS equipment, which have been issued by the European Telecommunications Standard Institute (ETSI).

Frequencies allocated for TFTS have been designated by the World Administrative Radio Conference, WARC-92 with frequency bandwidth of 2x5 MHz:

1670 – 1675 MHz, for ground to air

1800 – 1805 MHz, for air to ground.

TFTS planning is performed by the application of frequency blocks (42 blocks) with 164 channels in total. Bandwidth of each radio channel, which contains 4 speech channels, is equal to 30.3 kHz.

Due to the very high flight of the aircraft (about 13,000 m), it needs a long distance between the centres of cells (radio station on the ground) to avoid the co-channel or adjacent channel interference.

The article presents the planning process with typical cell radius of 240 km or 350 km. In the view of that fact, the need is pointed out for finding a compromise solution with regard to emitting power and the influence of interference.

Finally, it is noted that TFTS ground radio stations in Croatia, which are located in Zagreb and Split, may cover the territory of some neighbouring countries other than Croatia, which is important from the commercial point of view.

1. INTRODUCTION

There are a few possibilities today for making public telecommunication calls from passengers onboard aircraft to persons on the ground.

One of the possibilities is satellite communications with telecommunications service offered by "Inmarsat" (International Mobile Satellite Organization). This service is used only on long haul and ocean routes.

Some communications trials also have been undertaken at HF (High Frequency) band.

Terrestrial system for communications in the air traffic has been introduced in the United States within frequency band 800-900 MHz.

However, the frequency band of 800-900 MHz could not be applied in Europe, because of GSM system (Mobile System for Global Communications), which is operating at the same frequency band.

For all the above mentioned public telecommunications services the term Aeronautical Public Correspondence (APC) is used.

Since 1991, in Europe within CEPT (European Conference for Postal and Telecommunications Administrations) the necessary frequency bands for introduction of a Terrestrial Flight Telecommunications System (TFTS) have been considered, which were adopted at the World Administrative radio Conference (WARC-92). After the Conference, the planning process started in 1993 and has been completed now.

The operation of the TFTS will be performed through Ground Station Cells, and the radio link is supplied by ground stations, which will form a cellular network all over Europe.

That means, if the aircraft leaves the range of the ground station an automatic hand-over takes place and the call is not interrupted.

The main task in developing the TFTS system is the planning process with frequency efficient and coordinated allocations of channel blocks on a European basis.

An interference analysis needs also to be mentioned in order to allow undisturbed operation of the network.

2. DESIGNATED FREQUENCY BANDS

The frequency spectrum for both satellite and terrestrial Aeronautical Public Correspondence (APC) was designated at the World Administrative Conference for the Mobile Services (WARC MOB-87). However, limitations in the use of this spectrum, both in the bandwidth available and incompatibility with the existing services, prevented the introduction of operational systems.

Recognising the urgent requirement for APC and the difficulties associated with the spectrum allocated by WARC MOB-87, the European radio-communications Committee (ERC) undertook a study to identify suitable alternative frequency spectrum as part of its preparations for the World Administrative Conference 1992 (WARC-92).

ERC European Common Proposal for WARC-92 indicated the following frequency bands for Terrestrial Flight Telecommunications System:

- 1670-1675 MHz for ground to air
- 1800-1805 MHz for air to ground

These frequency bands (2x5 MHz) were adopted by the World Conference as an additional Footnote in the Radio Regulations (No. 740 A), which provides a world-wide allocation for those administrations wishing to implement APC.

ERC has recommended that designated frequency bands will be made available in a phased way (2x1 MHz in 1993, 2x3 MHz in 1994 and the complete band in 1998). This meets fully the traffic demands for TFTS as estimated by ETSI (European Telecommunications Standard Institute) by the year 2005.

3. PRINCIPLES OF THE PLANNING PROCESS

For introduction to the planning process, first of all it is to be pointed out that one should have a balanced approach in this respect. Optimising coverage and interference simultaneously is a conflicting problem.

If, for example one decides to raise the emitted power of the base station, it might on the other side cause interference problem. So, the main thing is to

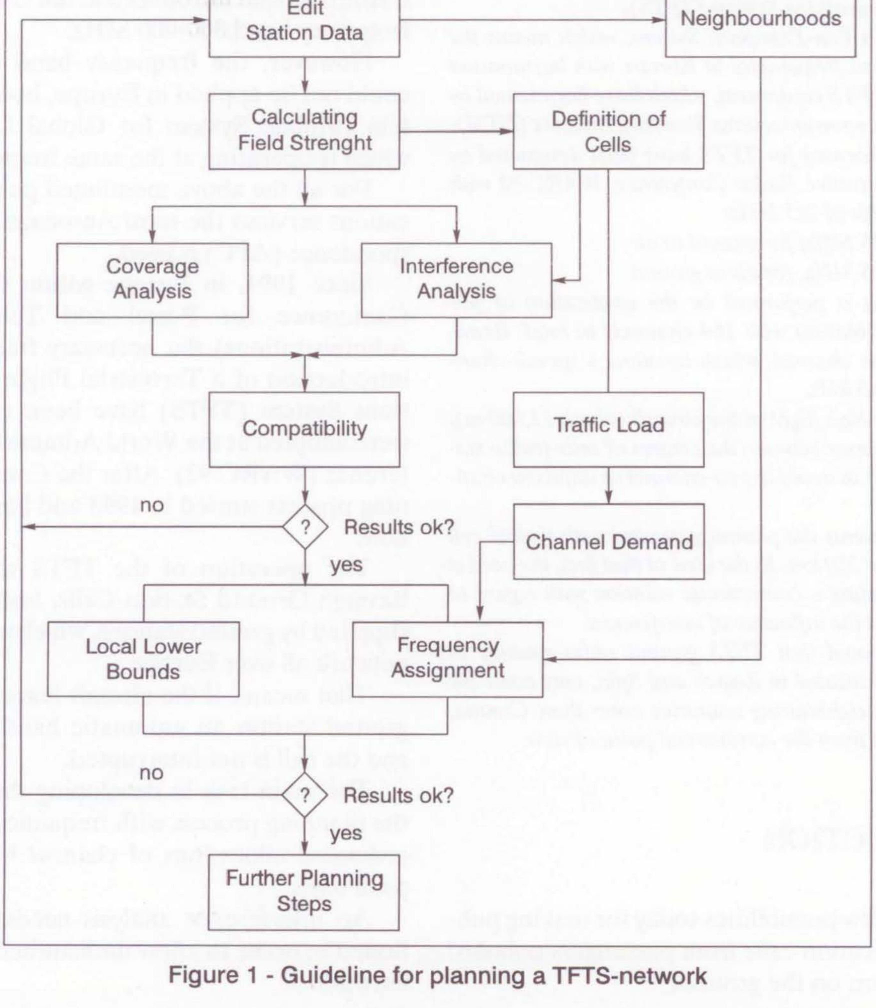

Figure 1 - Guideline for planning a TFTS-network

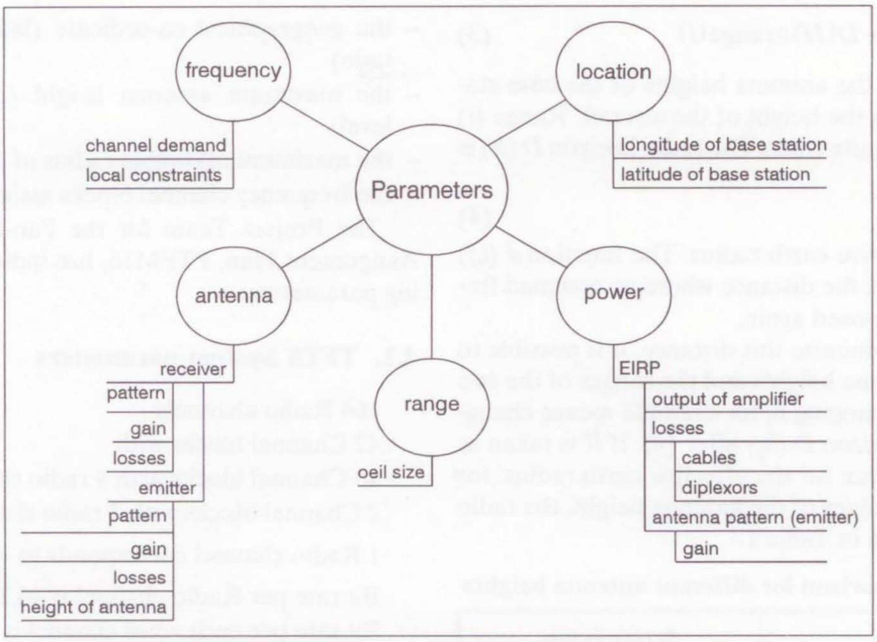

Figure 2 - Parameters, which influence the quality of the network (from a planning point of view)

find a compromise between the mentioned conflicting aspects.

It is necessary to consider the improvement of coverage and then the interference situation. If it is likely to be worsened, than one may try to optimise interference. Afterwards, the analysis of the coverage needs to be performed again and the process will continue in the way as indicated in Figure 1.

The entire optimisation procedure is subdivided in some main steps, and two of them are the analysis of coverage and interference.

Parameters which should be optimised in the planning process of the TFTS network are indicated in Figure 2.

The most important parameters in the planning process are the locations of the ground (base) stations and ranges of the base stations.

Typical values of the ranges are:

- 240 km, or 350 km for Enroute Stations (ER)
- ≤50 km for Intermediate Stations (INT)

Three categories of the ground stations can be mentioned here:

1. Enroute Stations, which are used for communications with an aircraft at its highest level (about 13,000 m height),
2. Intermediate Stations, which are used for communications with an aircraft at its medium level (about 6,000 m height), and
3. Airport stations (AS), which are used for communications with aircraft at its airport level.

There should be a correlation between the range and the emitted power, ERP (Effective Radiated Power) or EIRP (Equivalent Isotropic Radiated Power).

The received power at the aircraft is given by the following formula:

$$\frac{P_r}{dBm}=\frac{EIRP}{dBm}+\frac{G_r}{dB}-\frac{L_r}{dB}-32.4-20\log\frac{f}{MHz}-20\log\frac{d}{km} \quad (1)$$

Using typical values for the gain $G_r = 1$ dB and loss $L_r = 4$ dB of the receiving system and $f = 1670$ MHz, one gets the received power (dependant of the emitted power, *EIRP*, and the distance *d*) between emitter and receiver:

$$\frac{P_r}{dBm}=\frac{EIRP}{dBm}-20\log\frac{d}{km}-100 \quad (2)$$

For an Enroute Station (ER) the typical value of $EIRP = 49$ dBm. So, for the range of 240 km, the received power is $P_r = -99$ dBm.

Because of the receiver sensitivity at the aircraft of -112 dBm one can lower the emitted power by some dB (always keeping higher than the aircraft receiver sensitivity), and continue the next step with the planning process.

As far as the interference is concerned it is necessary to avoid it through the planning process or to minimise interference situation. Of course it is possible to avoid interference by assigning different and far distanced frequencies, but this is not a real situation.

Let us consider a pair *(i,j)* of two base stations. To avoid co-channel interference, the distance *d (i,j)* between them should be larger than:

$$d(i,j)>D(h_i)+D(H)+\text{range}(j)$$

$$d(i,j) > D(h_j) + D(H) + \text{range}(i) \quad (3)$$

h_i and h_j are the antenna heights of the base stations *i* and *j*. *H* is the height of the aircraft. Range (*i*) and range (*j*) is quite clear. The radio horizon *D* (*h*) is given by:

$$D(h) = \sqrt{2Rh} \quad (4)$$

R is the effective earth radius. The function *d* (*i,j*) fulfilling (3) gives the distance where an assigned frequency can be re-used again.

In order to minimise this distance, it is possible to change the antenna heights and the ranges of the two base stations. Changing h_j for example means changing the radio horizon D (h_j) after (4). If *R* is taken as R = 1.25 x 6371 km for the effective earth radius, for some different values of the antenna height, the radio horizon are given in Table 1.

Table 1- Radio horizon for different antenna heights

h_j in m	D (h_j) in km
200	56
150	49
100	40
50	28
0	0

However, changing the range from 240 to 180 km is more efficient. Formula (3) expresses it mathematically : The effect is linear in ranges but only proportionally to the square root of the antenna heights.

But, it is to be noted that an advantage of lowering the antenna height may be to make use of a shielding effect by topographic obstacles.

In addition the following cases are to be studied: an aircraft using a radio channel cannot only interfere with a ground station (and vice versa) using the same channel but also with one using the first and possibly the second and third adjacent channels.

To avoid co-channel interference at a TFTS receiver, the interfering signal (I) has to be considerably smaller than the wanted signal (carrier, C). A C/I ratio of 15 to 20 dB is deemed sufficient and can be achieved by assigning the channels in such a way that, for aircraft stations (AS) at the range limit of the cell, the interfering ground station (GS) is always at least 25 km behind the radio horizon.

4. BASIC CHARACTERISTICS OF TFTS NETWORK PLANNING

The European TFTS Assignment Plan (also called Schiver Plan named after the late TFTS Planning group chairman from Germany) indicates for each Ground Station the following information:

- the geographical co-ordinate (latitude and longitude)
- the maximum antenna height (above mean sea level)
- the maximum allowable radius of the service area
- the frequency channel blocks assigned.

The Project Team for the Pan-European TFTS Assignment Plan, PTFM16, has indicated the following parameters:

4.1. TFTS System parameters

164 Radio channels

42 Channel blocks with

40 Channel blocks with 4 radio channels

2 Channel blocks with 2 radio channels

1 Radio channel corresponds to 4 voice channels

Bit rate per Radio channel is 44,200 bit/s

Bit rate per each voice channel is 9,600 bit/s

The radio channel bandwidth is 30,303 kHz

1 channel block is 121,212 kHz

TFTS Channel Block Scheme with 42 Channel Blocks is indicated in Table 2.

Table 2 - TFTS Channel Block Scheme

Ch Block	Channels				Ch Block	Channels			
1	1	3	5	7	**2**	2	4	6	8
3	9	11	13	15	**4**	10	12	14	16
5	17	19	21	23	**6**	18	20	22	24
7	25	27	29	31	**8**	26	28	30	32
9	33	35	37	39	**10**	34	36	38	40
11	41	43	45	47	**12**	42	44	46	48
13	49	51	53	55	**14**	50	52	54	56
15	57	59	61	63	**16**	58	60	62	64
17	65	67	69	71	**18**	66	68	70	72
19	73	75	77	79	**20**	74	76	78	80
21	81	83	85	87	**22**	82	84	86	88
23	89	91	93	95	**24**	90	92	94	96
25	97	99	101	103	**26**	98	100	102	104
27	105	107	109	111	**28**	106	108	110	112
29	113	115	117	119	**30**	114	116	118	120
31	121	123	125	127	**32**	122	124	126	128
33	129	131	133	135	**34**	130	132	134	136
35	137	139	141	143	**36**	138	140	142	144
37	145	147	149	151	**38**	146	148	150	152
39	153	155	157	159	**40**	154	156	158	160
41	161	163			**42**	162	164		

4.2. Co-ordination distances

The minimum co-ordination distance between two ground stations depends on three factors:

- the coverage area (typically 240 km or 350 km radius)
- the radio horizon distances of neighbouring ground stations (dependant on the ground station heights)
- the altitude of the aircraft station (AS) about 13,000 m which corresponds to a horizon distance of 450 km.

It is also to be noted that the service distant of the cell of each Enroute Ground Station is at the minimum height of the aircraft of 4.6 km. For performing service below this height one may use the Intermediate Station (INT).

In the process of planning and implementation of the TFTS plan, co-ordination procedure between CEPT countries and non-CEPT countries should be within the responsibility of those countries who have border zones with Non-CEPT countries.

Assuming that all ground stations are similar height above sea level, ***the co-channel re-use distance*** is approximately as follows:

820 km (for 240 km cell radius)

1120 km (for 350 km cell radius)

Adjacent channel re-use distances (assuming the same conditions as for the cochannel reuse distance) are:

430 km (for 240 km cell radius)

530 km (for 350 km cell radius)

The calculations of interference due to the second and third adjacent channels indicated the protection ratio as 35 and 15 km. This means that stations should only be sited outside the range of a cell in which the second or third adjacent channel is used.

4.3. Receiver sensitivity

- for air station: -113 dBW/m^2 at +1 dBi antenna gain
- for ground station: -121 dBW/m^2 at +8 dBi antenna gain

5. REFLECTION OF THE TFTS PLANNING IN CROATIA

Croatia was very active during the planning process. Its representatives were in a position to give contributions in changing the acting plan when this process was underway.

So, two Enroute Ground Stations for Croatia are in the plan: Zagreb and Split with cell radius of 240 km (in the first attempt of the plan was only Split).

It is to be noted that coverage of the Ground Stations Zagreb and Split is larger than the Croatian territory.

Coverage of some neighbouring countries is indicated as follows:

Ground Station Zagreb:

- practically all of the territory of Slovenia,
- part of the territory of Bosnia and Herzegovina,

Table 3 - Main characteristics of Graund Stations in Croatia and neighbouring CEPT

CEPT Country	Ground (GS) Station Name	Latitude decimal degrees	Longitude decimal degrees	GS Antenna Height Above mean sea level	Maximal allowed Radius (km)	Proposed channel blocks No.
Albania	Tirana	41.350	19.800	70.00 m	240.00	23
Austria	Wien	48.167	16.333	70.00 m	240.00	18
Austria	Gaisberg	47.806	13.113	70.00 m	240.00	30
Croatia	Zagreb	45.900	15.950	30.00 m	240.00	7, 9
Croatia	Split	43.583	16.217	30.00 m	240.00	13
Hungary	Budapest	47.469	19.128	155.00 m	240.00	21
Italy	Monte Beigua	44.433	8.565	65.00 m	240.00	16, 29, 31, 33
Italy	Lugugnana	45.732	12.950	80.00 m	260.00	20, 22, 35, 37
Italy	Monte Lerno	40.606	9.166	37.00 m	280.00	5, 19, 21
Italy	Maschio Faete	41-747	12.730	15.00 m	260.00	15, 17, 24, 40
Italy	Monte Erice	38.035	12.582	38.00 m	280.00	30, 32, 34
Italy	Monte Mancuso	39.008	16.218	45.00 m	280.00	6, 8, 10
Slovenia	Ljubljana	45.929	14.475	30.00 m	240.00	1, 3

- part of the territory of Hungary,
- part of the territory of Austria.

Ground Station Split:

- practically all of the territory of Bosnia and Herzegovina,
- part of the territory of Italy,
- part of the territory of Yugoslavia (Monte Negro).

Main characteristics of the Ground Stations of Croatia and neighbouring countries have been presented in Table 3.

As far as the commercial interest is concerned, the future operation of the TFTS Ground Stations in Croatia could be profitable and one could also expect the bids for concessions in the future.

6. CONCLUSION

One of the possibilities for making public telecommunication calls from passengers onboard aircraft to people on the ground, is terrestrial telecommunications system, which is a part of Aeronautical Public Correspondence (APC).

The planning process for cellular terrestrial telecommunications system for such purposes in Europe is now completed and the system has been named as the Terrestrial Flight Telecommunications System (TFTS). This planning process was performed on the basis of co-ordinated allocations of channel blocks with 164 radio channels in total, considering on one hand the output power with cell range of Enroute Ground Stations and on the other hand the possible interferences. Those two components were calculated taking into account a compromise solution.

Locations of the Enroute Ground stations have been established with cell radius of 240 km or 350 km, having in mind that commercial height of aircraft flight is about 13,000 m.

Radio channels have been allocated to each cell taking into account the interference problem with co-channel and adjacent channel.

The TFTS system shall be implemented in Europe within CEPT countries by the year 1998 as a start and with complete implementation by the year 2005.

Through development of the air traffic in Europe, many countries as well as air traffic companies will benefit from implementing the TFTS system.

Croatia, with its two Enroute Ground Stations located in Zagreb and Split, having a coverage of some neighbouring countries, may organise a service provision to the foreign air traffic companies on their flight through those countries. Due to this fact, implementation of the TFTS system in Croatia might be expected as profitable one.

SAŽETAK

PRIMJENA NOVOG TERESTRIJALNOGA TELEKOMUNIKACIJSKOG SUSTAVA U EUROPSKOM ZRAČNOM PROMETU

Zrakoplovna javna korespondencija je telekomunikacijska usluga koja omogućuje putnicima na zrakoplovu da ostvaruje telekomunikacijske veze s ljudima na zemlji. U ovom članku se opisuje terestrijalna komunikacijska usluga, koja se zaniva na konceptu celularne mreže koja je planirana za europske zemlje članice CEPT-a (Europska konferencija poštanskih i telekomunikacijskih administracija) i naziva se Terestrijalni telekomunikacijski sustav za upotrebu na letovima (TFTS - Terrestrial Flight Telecommunications System). Radi se o paneuropskom sustavu što uključuje upotrebu harmoniziranih frekvencija u Europi uz harmonizirane norme za TFTS opremu, koje izdaje Europski institut za telekomunikacijske norme (ETSI - European Telecommunications Standard Institute).

Namijenjene frekvencije za TFTS određene su na Svjetskoj administrativnoj konferenciji WARC-92 sa širinom frekvencijskog pojasa 2x5 MHz:

1670-1675 MKz, smjer zemlja-zrakoplov

1800-1805 MHz, smjer zrakoplov-zemlja

Planiranje TFTS sustava izvedeno je primjenom frekvencijskih blokova (42 bloka) s ukupno 164 radio kanala. Širina svakog radio kanala, koji sadržava 4 govorna kanala, iznosi 30,3 kHz.

Zbog velike visine leta zrakoplova (oko 13000 m) potrebna je velika udaljenost između središta ćelija (radijskih postaja na zemlji) da bi se izbjegle smetnje istih ili susjednih kanala.

U članku je prikazan postupak planiranja s tipičnim radijusom ćelija od 240 km ili 350 km.Pri tome je naglašena potreba iznalaženja kompromisnih rješenja s obzirom na snagu emitiranja i utjecaj smetnji.

Na kraju je napomenuto da postaje za TFTS u Hrvatskoj, koje su locirane u Zagrebu i Splitu pokrivaju osim Hrvatske i područja nekih susjednih zemalja, što može biti interesantno s komercijalnog stajališta.

Također su tabelarno prikazane osnovne značajke hrvatskih postaja za TFTS i postaja susjednih zemalja članica CEPT-a.

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