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Some aspects about frequency hopping radio networks

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Abstract – As part of the management activity specific for modern frequency hopping radio systems, the interference studies include the Adjacent Channel Interference (ACI) level and the Co-Channel Interference (CCI) level. The paper is focused on the study of these interference levels and draws some conclusions regarding the use of FH radio systems. We will compare the use of radio hopping systems in two representative operating modes: fixed secure frequency and frequency hopping. The final aim of the paper is to improve the electromagnetic compatibility in a complex radio network, by offering a guide to facilitate the assignment and allocation of the radio resources.

Keywords: frequency hopping, interference, electromagnetic compatibility.

I. INTRODUCTION

The term "battlefield spectrum management" refers to managing electromagnetic spectrum resources in order to support telecommunications (including weapon systems) and electronic warfare (EW) requirements [1]. This type of management includes allocating and assigning generated frequency resources and the distribution of the variables for frequency hopping (FH) radio systems. The items of the management include frequencies, TSK (Transmission Security Keys) variables, net identifiers, COMSEC (Communications Security) variables, and time. However, equipment parameters impose some constraints on the distribution schemes for TSK, net identifiers, and frequency allocation schemes of the hop sets.

Radio frequency interference is inherent in all wireless systems and is one of the most significant design parameters of cellular and other mobile radio systems.

This paper investigates the power efficiency performance of frequency hopping radio systems operating in an adjacent channel interference (ACI) environment.

Adjacent Channel Interference (ACI) is caused by modulation, filter and radio design imperfections. Transmitted signal is not band-limited to a "brick wall" spectrum, so that some spectral power will be radiated into the adjacent channels (figure 1).

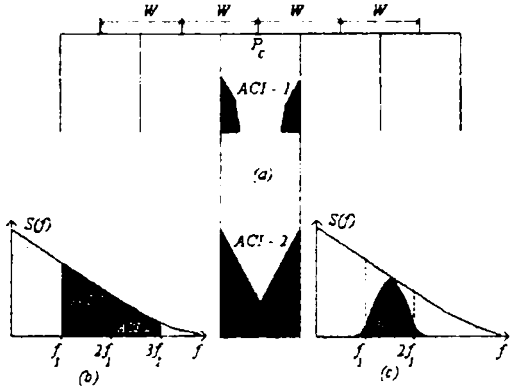

Fig. 1. Adjacent channel interference

Interference power caused by the first upper and lower interfering signals is designated as ACI-1 and the one caused by second signals is designated as ACI-2.

It is important to know the values of the spacing between channel (W) and bandwidth of the receiver filter. In several system specifications the receiver filter is assumed to be a "brick wall" filter [2].

The integrated (total) ACI power can be expressed as [2]:

$$ACI = A(WT_b) = \frac{\int_{-\infty}^{\infty} S_y(f)\left|H(f-w)\right|^2 df}{\int_{-\infty}^{\infty} S_y(f)\left|H(f)\right|^2 df} \qquad (1)$$

where: $S_y(f)$ is the power signal density (PSD) of the signal; $H(f)$ is the receive filter transfer function; $w = WT_b$ is the normalised carrier spacing between adjacent channel.

The method used to assess the ACI levels is a practical one and is based on measuring this parameter in two representative operating modes: the fixed secure frequency mode and frequency hopping mode.

The instrument we used is a R&S FSH3 Spectral Analyzer [3]. Comparing the results we can provide

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an efficient allocation of the resources for frequency hopping radio systems.

II. RESULTS AND DISCUSSION

The results are representative for a simple tactical network where the power of the frequency hopping systems is uniform distributed in the coverage area. Fixed secure operation mode is one specific for frequency hopping systems due to the spectral performance in the critical cases of propagation like urban or mountain areas. The levels of ACI are presented in figure 2 and more details are shown in table 1.

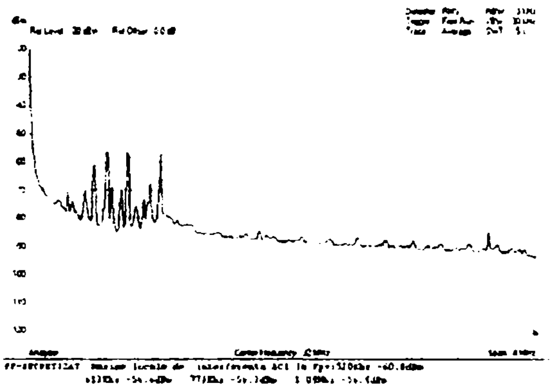

Fig. 2. The ACI levels in the Fixed Secure Frequency Mode

Table 1

Frequency distance (kHz)	Attenuation (dB)
100	58.5
300	69
500	72.8
526	**60.8**
600	73.9
626	**56.6**
700	75.2
780	**56.3**
800	76.3
1040	**56.4**
1100	77.9
1400	78
1600	78.4

We can observe maximum ACI levels for several frequency distances. The frequency positions of these levels remain constant for variable value of the hopping system operation frequency. The spectrum manager must avoid these frequencies.

A secure operation mode, specific for a jamming environment, is the frequency hopping one. The equipment capabilities provide narrow or wide band hopping modes. Our interest is only to estimate the ACI level, so it is recommended to use the narrow hopping mode. Using a different frequency position in the narrow hopping band, ACI level values can be observed for a variable operation frequency of the equipment. Due to the limited spectral analyzer capability we are focused only to the results between two frequencies of the successive hopps. The values of these frequencies are 35 MHz and 36 MHz. For a hop speed of 100 hops/s, it is necessary to set the acquisition time of the analyzer to 20 ms. The ACI levels are presented in figures 3, 4 and figure 5. More details are shown in table 2.

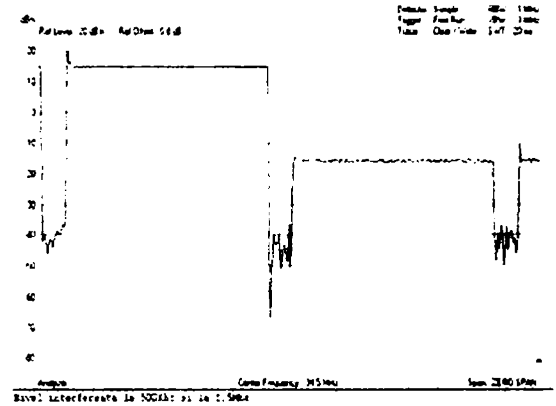

Fig. 3. The ACI levels in the Hopping Frequency Mode at a frequency distance of 500kHz and 1.5MHz.

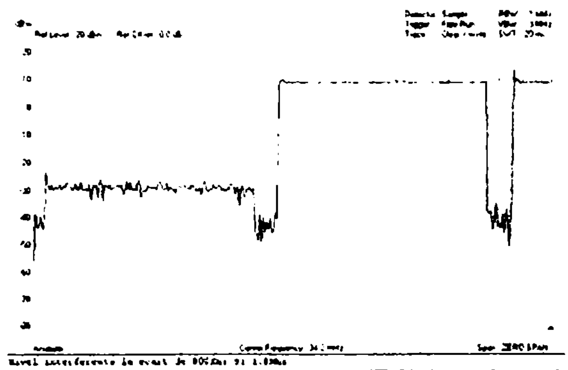

Fig. 4. The ACI levels in the Hopping Frequency Mode at a frequency distance of 800kHz and 1.8MHz.

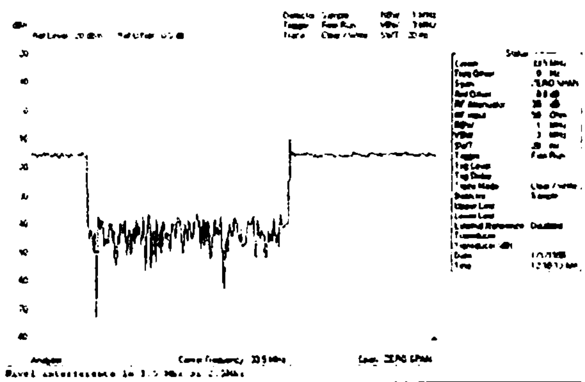

Fig. 5. The ACI levels in the Hopping Frequency Mode at a frequency distance of 1.5MHz and 2.5MHz.

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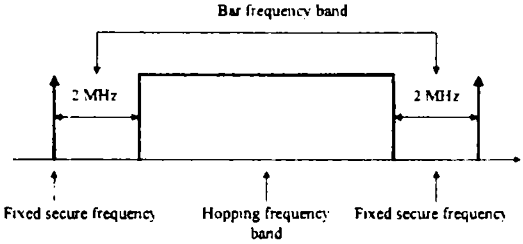
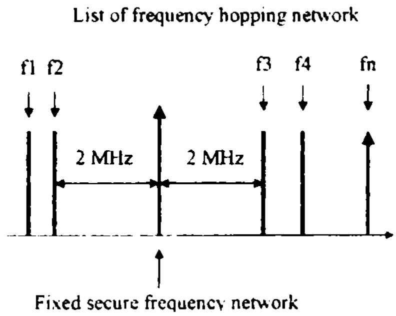
Table 2

Frequency distance (kHz)	Attenuation (dB)
200	0.3
300	0.9
500	4.4
700	6.2
800	8.9
900	14.5
1100	18.1
1200	20.9
1300	25.4
1400	29.3
1500	34
1600	37.9
1700	43
2000	50

Comparing with fixed secure mode, one can observe increased values of the ACI levels. An acceptable 40 dB ACI level requirement imposes a minimum of 1.7 MHz frequency distance. This means considerable constraints in the process of managing the radio resources.





III. CONCLUSION

In this paper we investigate the ACI level for frequency hopping systems in two representative operating modes: fixed secure frequency and frequency hopping.

Fixed secure mode provides good spectral efficiency but is easy to detect by the enemy.

Frequency hopping mode is less power efficient but provides ECCM (Electronic Counter Counter Measures) communications.

In the process of resources planning it is recommended to combine the advantages of both operation modes, so we expect to have, in same area, complex radio networks.

A simplified situation is presented in figure 6 where the spectrum manager must allocate the frequency resource between two radio networks, one operating on a fixed secure frequency and second one operating in the frequency hopping mode.

A minimum 2 MHz frequency distance, upper or lower, is requested between the frequency resources of the radio networks, if a 40-dB ACI level performance is considered.

Another situation is the one represented in figure 7, where the frequency hopping radio network is a particular one, operating with a list of frequencies. A minimum of 4 MHz frequency distance is recommended between two consecutive frequencies of hopping list. This requirement is necessary only in the case of inserting the frequency value of the fixed secure network.

The situation that we considered in this paper is valid only in the case of uniform power of the frequency hopping equipment.

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