



Report ITU-R S.2150
(09/2009)

**An interference reduction technique by
adaptive-array earth station antennas for
sharing between the fixed-satellite
service and fixed / mobile services**

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REPORT ITU-R S.2150

**An interference reduction technique by adaptive-array earth station antennas
for sharing between the fixed-satellite service and fixed/mobile services**

(2009)

Scope

This Report describes an interference reduction technique using adaptive-array earth station antennas for sharing between the FSS and fixed/mobile services. This technique may be used to improve FSS link performance when sharing the same frequency band with other services. The Report contains the theoretical analysis and field test results as well as observations to provide guidelines for the system design when employing the interference reduction technique.

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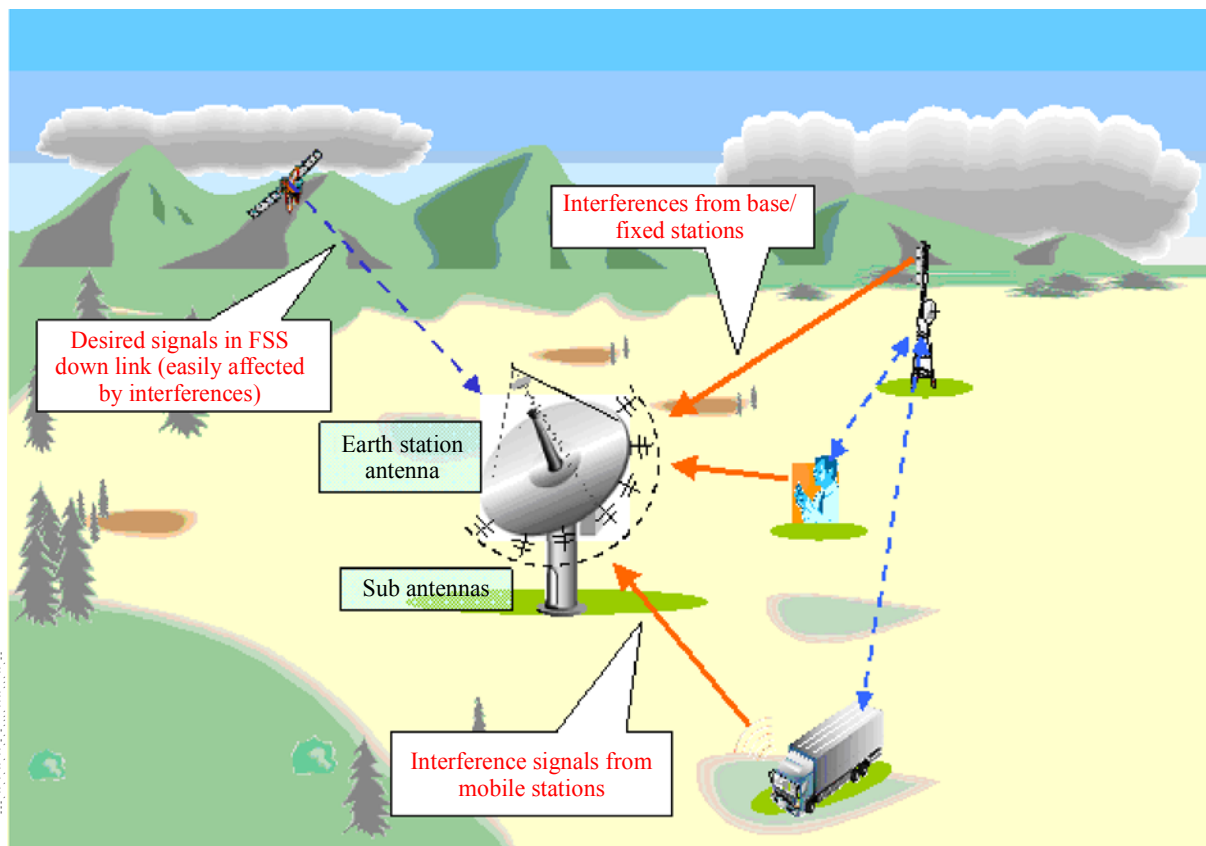
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1 Introduction

As one of the possible measures to improve link performance of the fixed-satellite service (FSS) systems, an interference reduction technique by adaptive-array antenna would be considered.

In this technique, as shown in Fig. 1, interference signals from stations of fixed/mobile services (i.e. base/fixed stations or mobile stations) are reduced at a FSS earth station antenna by digitally processing signals received at a main earth station antenna (denoted as “main antenna” hereafter) and sub-antennas aligned around the main antenna. Each sub-antenna has the directivity in the horizontal plane and covers a part of the direction that interference signals arrive.

FIGURE 1
Overall concept for interference reduction



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In this Report, the overview of interference reduction technique using adaptive-array antennas is presented firstly. Next, the theoretical analysis and implementation of prototype interference reduction is discussed. Subsequently, test results of field trials conducted in a satellite teleport are presented. Finally, consideration of test results and system design guidelines are provided.

It should be noted that this Report addresses only the technical aspects of the presented interference reduction technique. As with any technology or interference reduction technique, there will be tradeoffs associated with balancing the complexity and cost of implementing the technique with the benefit derived from its implementation. Analysis of such tradeoffs is beyond the scope of this Report as such tradeoffs will be unique to every situation. The reader is advised that cost/benefit considerations are very important and should be carefully weighed when considering the possible implementation of such technologies.

2 Overview of interference reduction technique using adaptive-array antennas

Figure 2 depicts the principle of the interference reduction technique using adaptive-array antennas. A number of sub-antennas (N sub-antennas) are aligned around the main antenna. The number of interferers is assumed to be M in this case.

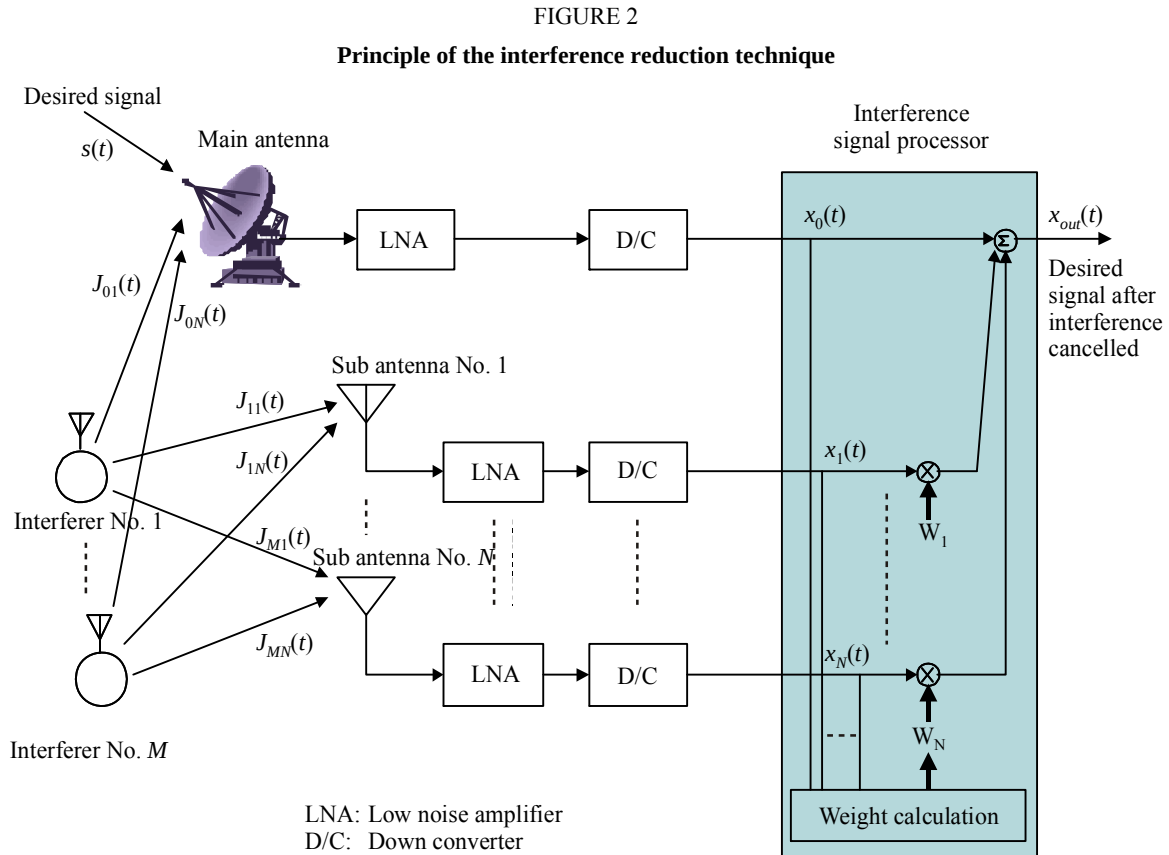
At the main antenna, the interfering signals ($J_{01}(t)$ to $J_{0M}(t)$: either from mobile stations or base/fixed stations) are received in addition to the desired signal from a satellite $s(t)$. The signal received at the main antenna, $x_0(t)$, is expressed by:

$$x_0(t) = s(t) + J_{01}(t) + \dots + J_{0M}(t) \quad (1)$$

At the sub-antennas (No. 1 to No. N), only the interfering signals are received and no desired signal is received since the antenna gain of sub-antennas towards the satellite is too low to sense the very weak signal from the satellite. As a result, the signal received at the k -th sub-antenna $x_k(t)$ is expressed by:

$$x_k(t) = J_{k1}(t) + \dots + J_{kM}(t) \quad (2)$$

Aggregated signals received at the main and sub-antennas ($= x_0(t) + x_1(t) + \dots + x_N(t)$) are digitally processed by the “interference signal processor” (ISP) in Fig. 2.



Consequently, the following signal is produced as a desired signal after interference reduction:

$$x_{out}(t) = x_0(t) + \sum_{k=1}^N w_k \cdot x_k(t) \quad (3)$$

where w_k is a weighting factor (or “weight”), that is adaptively computed by the interference signal processor, to multiply to the received signal at the k -th sub-antenna in order to minimize interference signals.

3 Theoretical analysis on the performance of interference reduction

Figure 3 shows a simple model to estimate the performance of interference reduction. By the principle of interference reduction technique, the system noise of the main antenna (i.e. the path for the desired signal) increases due to the additional noise incurred by the sub-antenna even though the operation of “correlation” (or calculation of weight) in Fig. 3 is ideal. The residual noise after the interference reduction (i.e. the increment noise as to the original system thermal noise without interferences), r , is expressed by:

$$r = \frac{\frac{I_1}{N_1}}{\frac{I_2}{N_2}} \quad (4)$$

where I_1 , N_1 and S_1 represent the received levels of the interference signal, system thermal noise(excluding the interference) and desired signal at the main antenna and I_2 and N_2 represent those at the sub-antennas. The value r is regarded as a theoretical limit of the interference reduction technique in terms of incremental noise.

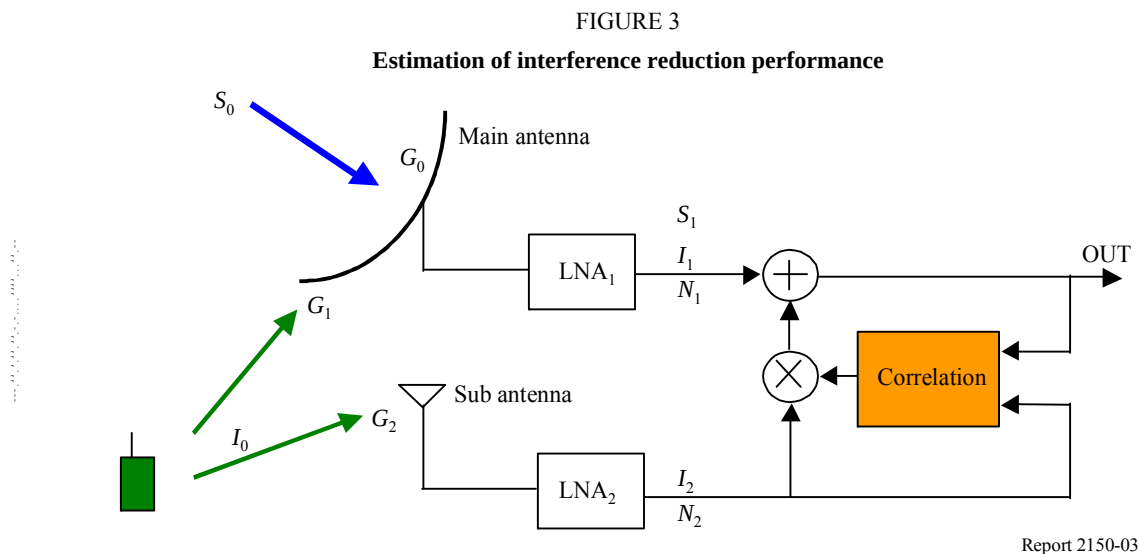


Table 1 shows an example set of parameters. Assuming that the propagation loss from the interferer to the main antenna is equivalent to that to the sub-antenna, I_1/I_2 is proportional to the ratio of antenna gain between the main and sub-antenna in the direction of the interference arrival

(i.e. G_1/G_2). N_1/N_2 is proportional to the ratio of system noise between the main and sub-antennas. For receiving the benefit of interference reduction, it is necessary to keep the value of G_1/G_2 as small as possible.

TABLE 1
Example parameters

Category	Item	Value	Note
Interfering signal	Frequency	3 900 MHz	Note 1
	Bandwidth	20 MHz	
	Transmit e.i.r.p. No. 1	46 dBm	For base stations
	Transmit e.i.r.p. No. 2	30 dBm	For mobile stations
Main antenna	Antenna gain	−10 dBi	$\Phi > 48^\circ$ (Ref. Recommendation ITU-R S.465)
	System noise temperature	100 K	
Sub-antenna	Antenna gain	8 dBi	
	System noise temperature	400 K	

NOTE 1 – The purpose of 4 GHz band in Table 1 is to align the field trial described in § 5 of this Report and the applicability of the technique is not limited to particular frequency bands.

From the parameters shown in Table 1, the value of r is calculated as −12 dB, which corresponds to approximately 6% increase of the system noise floor of received FSS downlink. In this case, the G_1/G_2 is −18 dB. Note that further improvement could be expected since the antenna gain of the main antenna in the side-lobe region is typically better than −10 dBi in many cases. However, by the nature of interference reduction technique, it would be difficult to cancel the interference arriving from boresite direction of the main antenna.

Figure 4A/4B shows the relation between the distance to interferer and the I/N value and received level at the main antenna based on the parameters in Table 1. It is assumed that the interferer is either a mobile station or a base/ fixed station (single entry). Theoretically, the interference signal could be cancelled with the residual noise determined by equation (4) above left. The difference between the input I/N (before interface reduction) and the residual I/N (after interface reduction) is defined as the “reduction gain” as illustrated in Fig. 4A.

Naturally, the smaller the distance to interferer (or the larger received interference signal level), the larger the required reduction gain. For instance, it is seen from Fig. 4A that more than 40 dB reduction gain is required when the distance to interfering base station is within 2 000 m. The required reduction gain would have an influence on the design of the interference signal processor (e.g. the number of bits in computation to determine the dynamic range and so forth).

Furthermore, the maximum received level shown in Fig. 4B would be important in the system design to ensure the front-end LNA (Low noise amplifier) of the main antenna is not saturated. Typically, the maximum permissible level at the LNA input is around −65 dBm in aggregation. Operational scenarios (distance to interferers and transmit power of interferer) should be determined taking into account these elements.