International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.2069-0

(12/2014)

Antenna rotation variability and effects on antenna coupling for radar interference analysis

M Series

Mobile, radiodetermination, amateur and related satellite services

150
1865 - 2015

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	**Mobile, radiodetermination, amateur and related satellite services**
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2015

RECOMMENDATION ITU-R M.2069-0

Antenna rotation variability and effects on antenna coupling for radar interference analysis

(2014)

Scope

This Recommendation describes the effect of antenna rotation on antenna coupling for interference and compatibility analysis.

Keywords

Antenna coupling, antenna rotation mismatch, radar

Abbreviations/Glossary

CDF cumulative distribution function

The ITU Radiocommunication Assembly,

considering

a) that there is a need to estimate antenna coupling of rotating antennas for use in interference assessments;

b) that Recommendation ITU-R M.1851 – Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses, can be used to obtain theoretical antenna patterns to be used in antenna coupling estimates,

recommends

that for estimating the effects of antenna coupling, the information described in Annex 1 should be considered.

Annex 1

Antenna coupling effects

In this annex, the effects of antenna rotation variability on antenna coupling are discussed.

Antenna coupling

When two radars are operating within line of sight of one another, or when anomalous propagation conditions allow, the radiation from one radar antenna can be received by the other radar's antenna and its associated receiver. This interaction could result in mutual interference which would lead to performance degradation. When this situation happens, the two systems are said to be coupled. The magnitude of antenna coupling between the two radars must be calculated in order to anticipate any problems caused by the offending system and to implement relevant preventative measures. Antenna coupling between two radars depends on:

– atmospheric propagation conditions;
– the power of the transmitter;
– the losses due to the cables and other units of both systems;
– the coupling between the antennas due to radiation patterns;
– the sensitivity of the victim receiver;
– spatial separation and terrain elevations between the radars;
– antenna heights above the ground and antenna elevation tilt angle;
– the absolute gains of the antennas at the angles at which the direct rays leave the transmit antenna and are incident on the receive antenna, and
– the mismatch in the antenna rotation rates.

Primary radars use highly sensitive receivers in order to detect aircraft reflected signals with two way propagation losses (forward and return paths), affecting the radar's equation by $1/R^4$ where R is the aircraft distance.

Radar to radar interference is a one way path ($1/R^2$ propagation path) that results in a larger required separation distance between the interfering and victim radar.

With such considerations, we can conclude that in a full radar coverage network, radars will always have interferences with other surrounding radars.

Radar to radar coupling occurs mainly then both radars are operating co-frequency or in frequency vicinity where the frequency dependent rejection (FDR) or peak FDR value is small. So, in order to suppress these radar-to-radar interferences, the current mitigation technique is to attribute different frequencies to radars in the coverage area. A set of frequencies, with sufficient frequency separation are needed to reduce interference, and to obtain a full coverage of a region through a geographical frequency plan.

The rotational speed mismatch between two antennas can cause high levels of interference to be repetitive and long lasting. Figures 1 to 6 show examples of antenna rotation mismatch (Rec. ITU-R M.1464-1 Radar-C to Radar-C). This mismatch in rotational speed is not unreasonable. For example, the following are sample requirement specifications for airport surveillance radar pedestal azimuth drive and antenna scan rate requirements:

> *"<u>Antenna Pedestal Azimuth Drive</u>. The pedestal azimuth drive shall have a controllable velocity of 0 to 30 degrees per second in steps no greater than 1 degree per second with accuracy of ±0.5 °/s. The azimuth drive positions and holds the antenna within ±0.05 degrees of the selected azimuth angle when commanded. In normal operation, antenna rotation is in the clockwise direction."*

Another specification for antenna scan rate states that "antenna scan rate is one revolution every 4.8 seconds, +0.53 or –0.44 second" this equates to antenna rotation values between 67.54°/s to 82.57°/s.

This above specification means that even if the antennas are synchronized in rotation, high levels of antenna coupling can occur. The results of antenna coupling for three values of two radar antenna rotation mismatches of a maximum of 0.5°/s, 0.25°/s and 7.46°/s are shown in the figures below. It is shown that as the antenna rotation speed mismatch is reduced, the repetition rate of high level of antenna couplings is reduced.

FIGURE 1

Antenna coupling with rotation rate difference of 0.50°/s

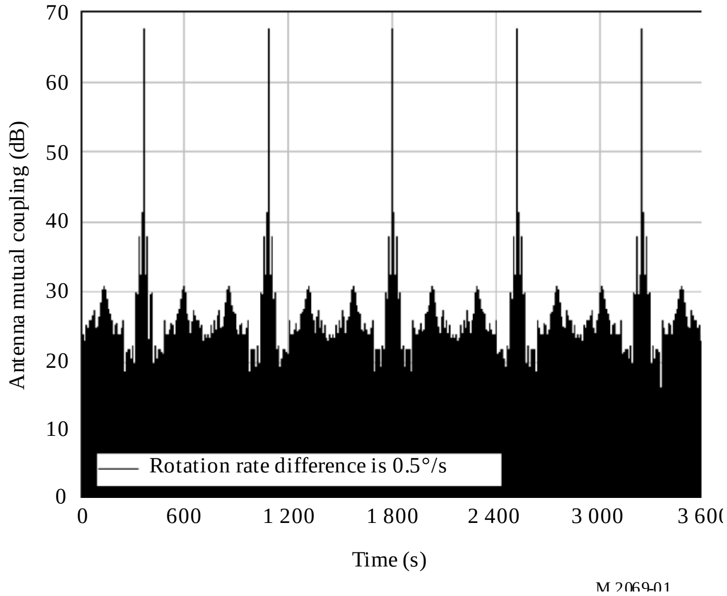


FIGURE 2

Antenna coupling with rotation rate difference of 0.50°/s (more details)

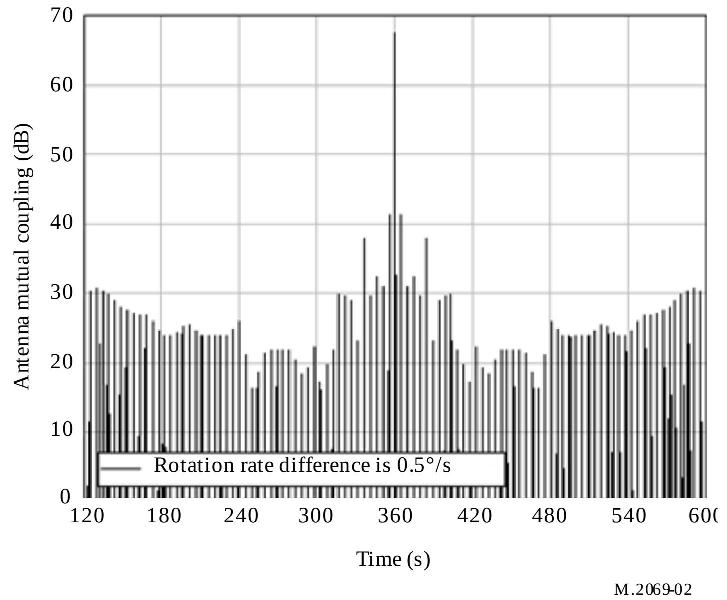


FIGURE 3

Antenna coupling with rotation rate difference of 0.25°/s

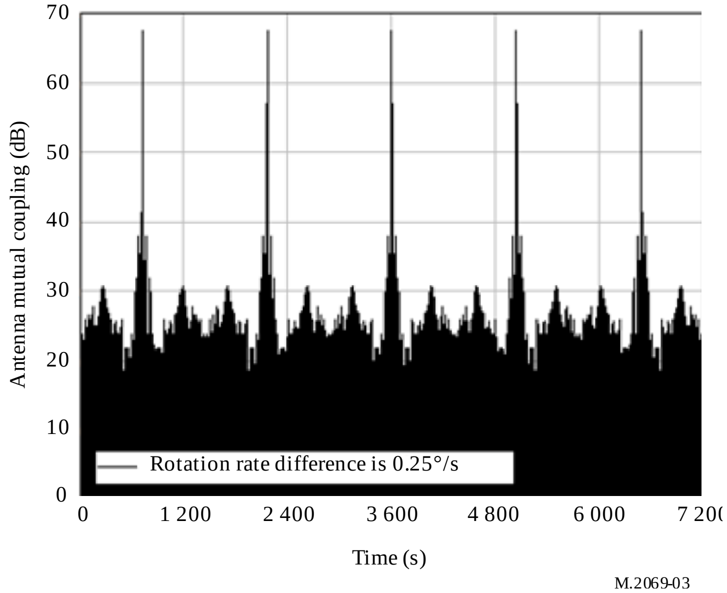


FIGURE 4

Antenna coupling with rotation rate difference of 0.25°/s (more details)

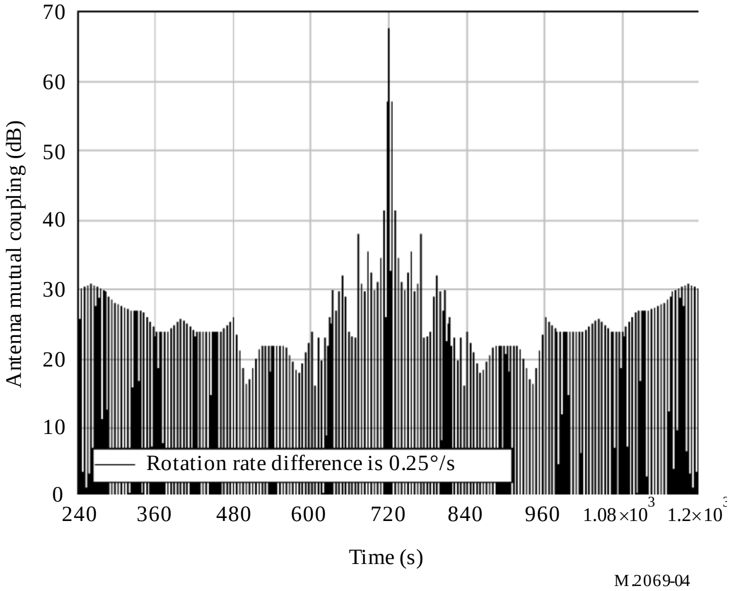


FIGURE 5

Antenna coupling with rotation rate difference of 7.46°/s

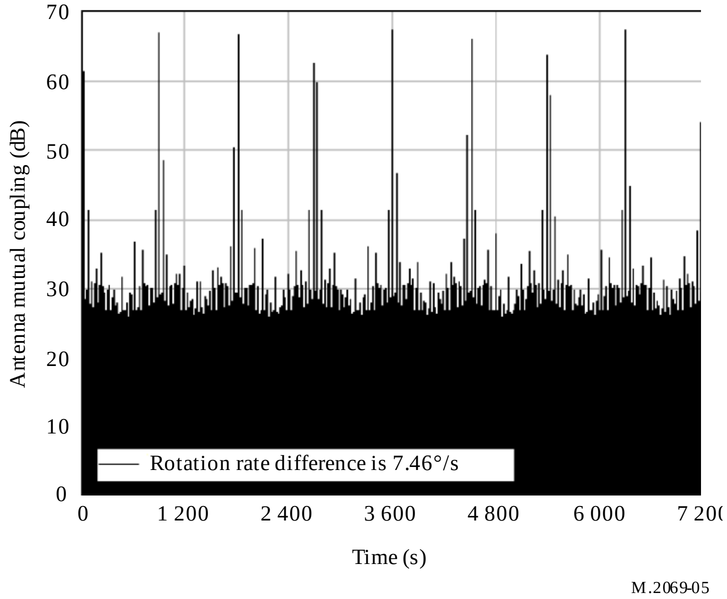


FIGURE 6

Antenna coupling with rotation rate difference of 7.46°/s (more details)

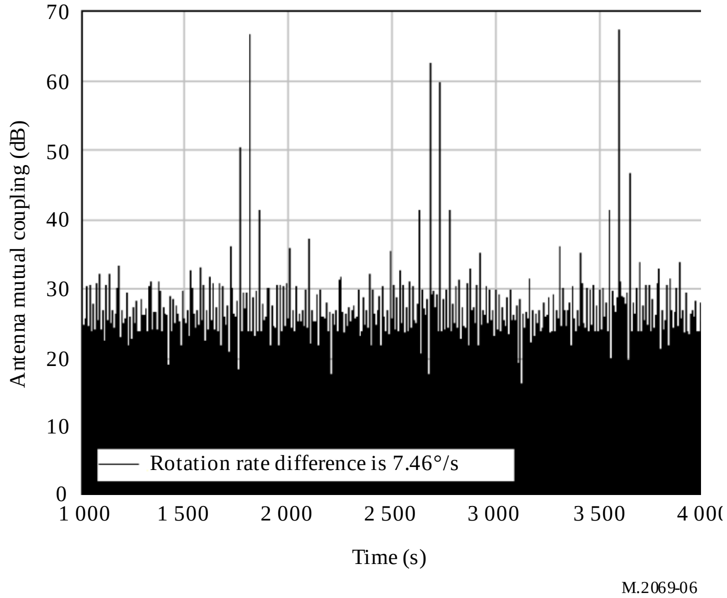


FIGURE 7

Antenna coupling with rotation rate difference of 7.46°/s with multiple radars

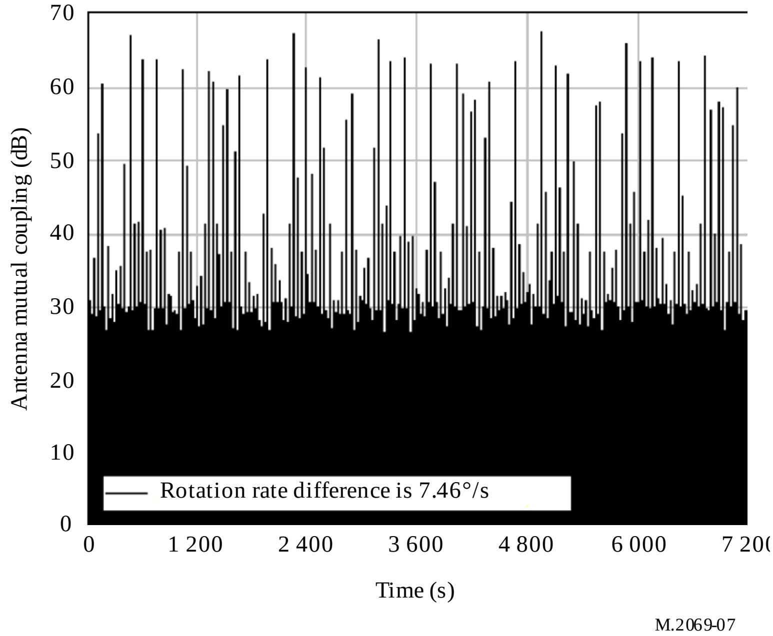
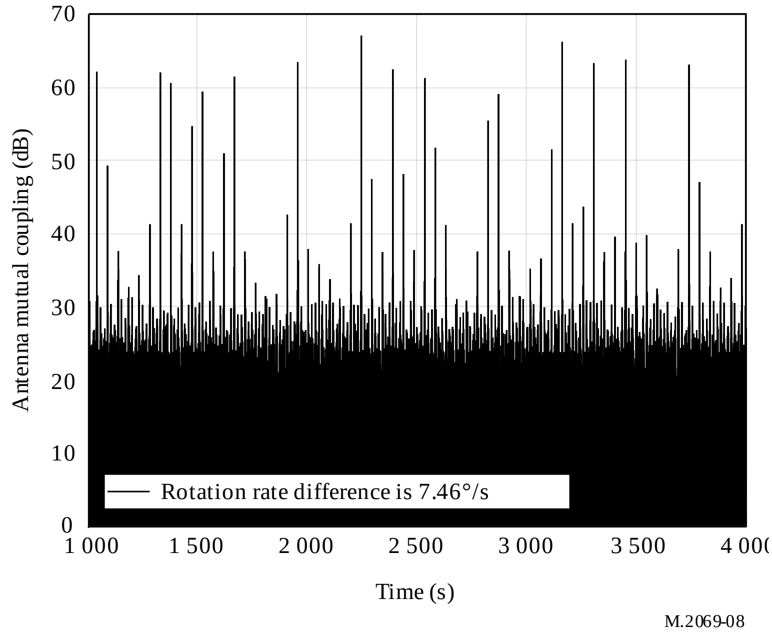


FIGURE 8

Antenna coupling with rotation rate difference of 7.46°/s with multiple radars (more details)

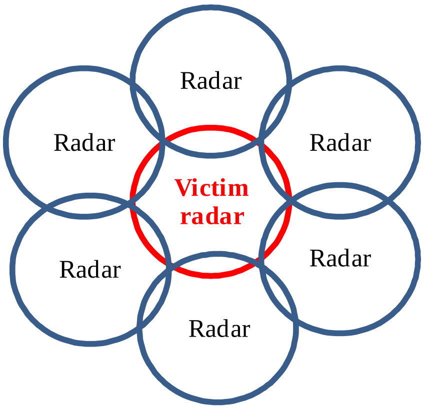


As can be seen in Figs 1 to 8 a high level of antenna coupling gains can be present for long time duration depending on the value of antenna rotation speed mismatch. Figure 10 shows the antenna coupling cumulative distribution function (CDF) for Radar-C to Radar-C (antenna pattern given in Fig. 11) interaction calculated by taking 5 Million random samples of two radar (and of multiple Radar-Cs interfering with one Radar-C, see Fig. 9) antennas azimuthal pointing positions and evaluating the total gain as seen by the victim antenna. The rotation rates are assumed not to be identical. The radars are placed such that the antennas are considered to provide far field patterns. As an example, coupling levels of +30 dB between the two radars is exceeded for 0.05% of the time. However, from the above plots that 30 dB level is almost always exceeded. Therefore, it is necessary to choose a value much less than 0.05% in order to represent realistic antenna coupling values. When doing sharing and compatibility studies, it is recommended that the antenna coupling gain should be selected such that it is not exceeded more than a very small amount of time. The magnitude of the "very small" will be determined on a case-by-case basis depending on the criticality and importance of the radar function. In addition, the following remarks are added:

Multiple radars effect

It should also be noted that coverage of large areas could require a network of radars. For example, in order to have a full coverage, without any blind spots, we could consider that a victim radar is surrounded by 6 other radars (see Fig. 9).

FIGURE 9

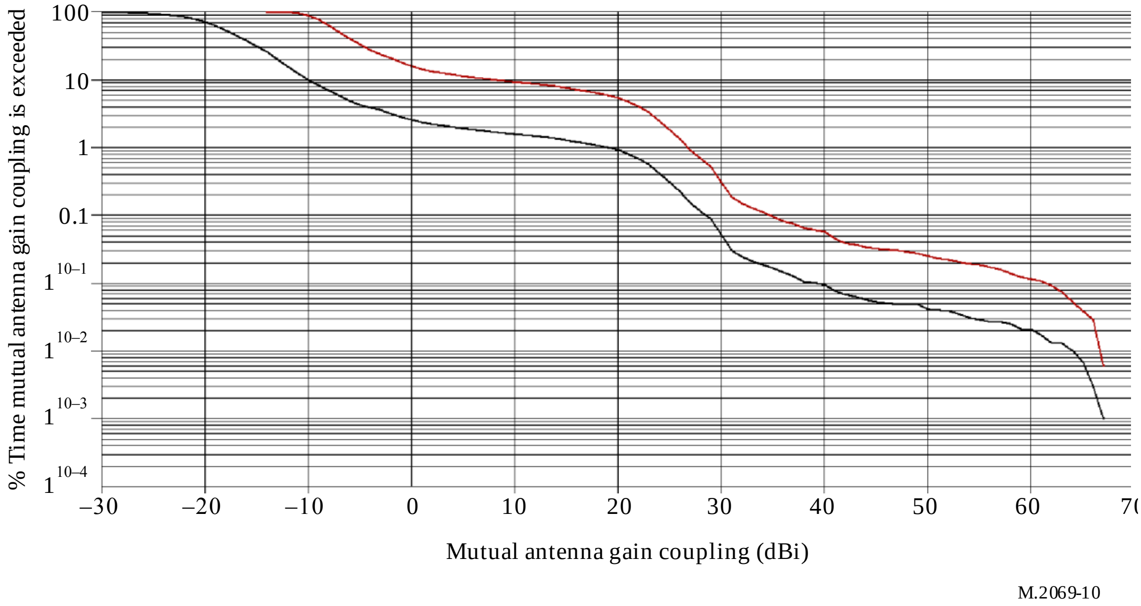


In such case, interferences occur roughly "six times more often". Due to the different angular positions of the seven radars and differences in rotation position, the interferences occurrences will have a staggered distribution in time.

For example, with antennas' rotation rate difference of 0.1°/s, in a case of uniform recurrence hypothesis, the period for maximum coupling events could be estimated at every (360° ÷ 0.1°/s) ÷ 6 = 600 s. But in another extreme case, the maximum coupling events between the victim radar with the other six surrounding radars could appear during the same rotation period of the victim radar's antenna. With a common rotation period of radar antenna of 12s, it means that the victim radar has interference every 2 seconds. Figure 10 shows the antenna coupling CDF for two cases. The first is for one-on-one radar coupling (black colour curve) and the second (red colour curve) is for six radars interfering with one radar placed in the middle as shown in Fig. 9.

FIGURE 10

Antenna coupling CDF for radars C
(using antenna pattern measurements)



The antenna patterns used for the analysis are shown in Fig. 11.

FIGURE 11

Radar-C (Rec. ITU-R M.1464) pattern from measurements (Fig. 11)

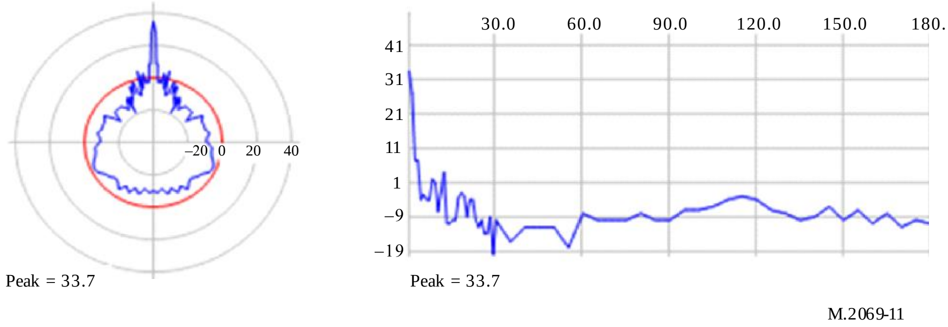
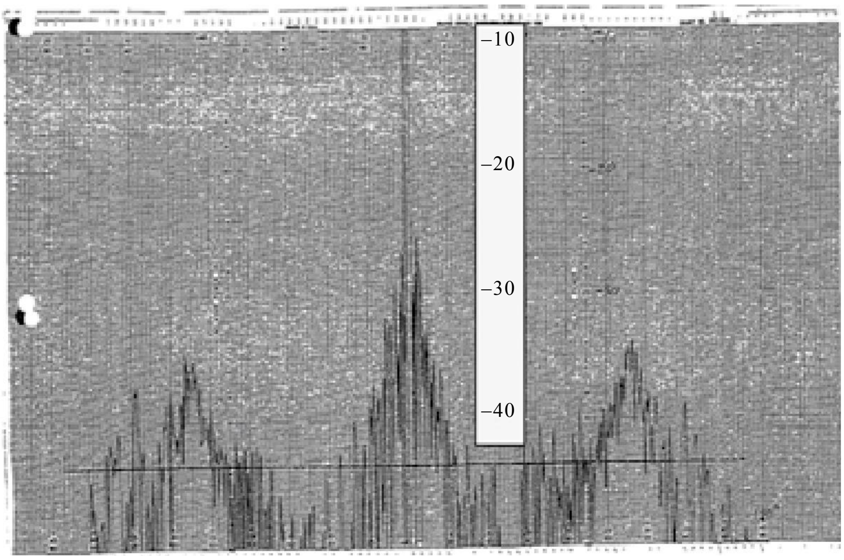


Figure 12 shows measured patterns for radars equivalent to Radars C.

FIGURE 12

Radar-C antenna pattern measurements



M.2069-12

Conclusions

Is has been shown that high radar to radar antenna coupling values can repeat consistently for long time duration. The effect of this coupling should be accounted for by using the appropriate value from antenna coupling CDF calculation taking into account the radar function criticality.

References

[1] ATDI Contract No. N68836-10-P-1705 "Rivira Wind Farm Effect on Kingsville Naval Air Station Radar" Written by S. Yun, M. Rais.

[2] faaco.faa.gov/attachments/TDWR_Antenna_Requirements.doc.

[3] Thereza M. Macnamara BSc, MSc (London) "Introduction to Antenna Placement and Installation" A John Wiley and Sons, Ltd., Publication, 2010.