



Technical Challenges to Spectrum Sharing Between Radars and Non-Radar (Communication) Systems

7th Annual ISART
Boulder, Colorado
1 March 2005

Frank Sanders
Chief, ITS Telecommunications Theory Division,
U.S. Department of Commerce, NTIA
325 Broadway, Boulder, CO
fsanders@its.blrdoc.gov
303.497.7600



Introduction

Proposals have been made in recent years for operation of communication systems in radiolocation (radar) bands. Some of these proposals have originated from non-US Administrations in the International Telecommunications Union Radiocommunication Sector (ITU-R).

These proposals represent a change from the historical approach of allocating radar and communication systems in separate bands. This segregation has been due to perceived electromagnetic incompatibility between the radar and communication services.

A variety of technical justifications have been made for spectrum sharing between radars and non-radar communication systems. This talk addresses the technical challenges of such sharing, based on results of spectrum surveys and interference studies.



Justifications provided for sharing

- 1) Radar systems make little use of existing spectrum allocations;
- 2) Radar receiver performance is inherently robust against interference from signals of other, non-radar services;
- 3) To the extent that sharing might cause interference to radars, it might be accommodated on some sort of statistical basis;
- 4) If spectrum sharing were to cause intolerable interference to radars, then spectrum could still be shared but communication devices would have to sense radar signals and avoid frequencies being used locally by radars.



Evaluation of these hypotheses...

...could make available opportunities for new patterns of spectrum use. But careful technical consideration needs to be done to test these concepts. We will consider the four hypotheses in order...



Measured spectrum utilization of radars

Radars usually consist of high power transmitters operating in concert with very sensitive receivers. EIRP transmit levels are often more than 1 GW, while receiver noise figures are often only a few decibels above the theoretical thermal noise limit.

Representative radar emission parameters as a function of mission.

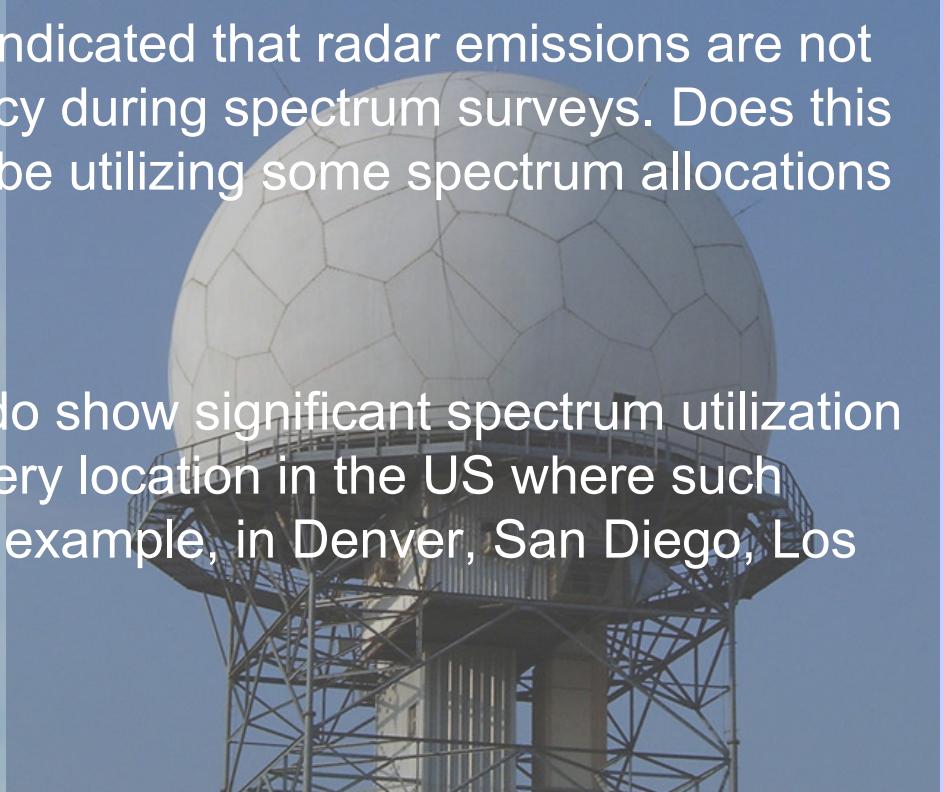
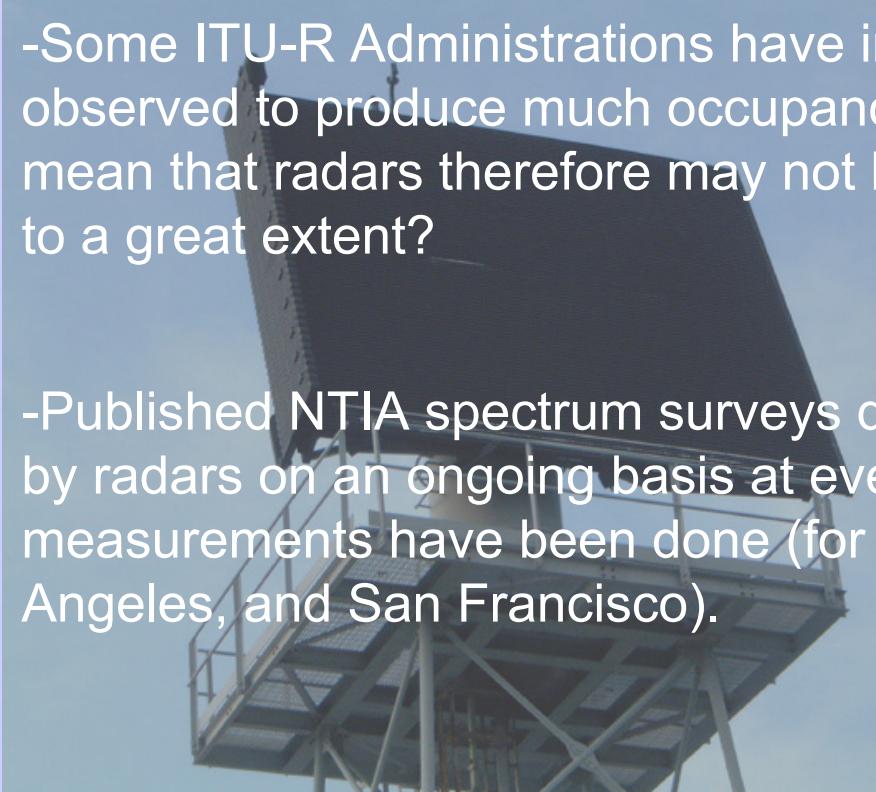
Mission	Pulse width (us)	Pulse rate (Hz)	Peak power (MW)	Antenna gain (dBi)	PeakEIRP (GW)
Short range air search	1	1000	0.8	33	1.6
Long range air search	3-10	300	1	33	2
Maritime navigation	0.08-0.8	10000	0.02	30	0.02
Weather	1-5	300-1300	0.75	45	24



Measured spectrum utilization of radars, continued

-Some ITU-R Administrations have indicated that radar emissions are not observed to produce much occupancy during spectrum surveys. Does this mean that radars therefore may not be utilizing some spectrum allocations to a great extent?

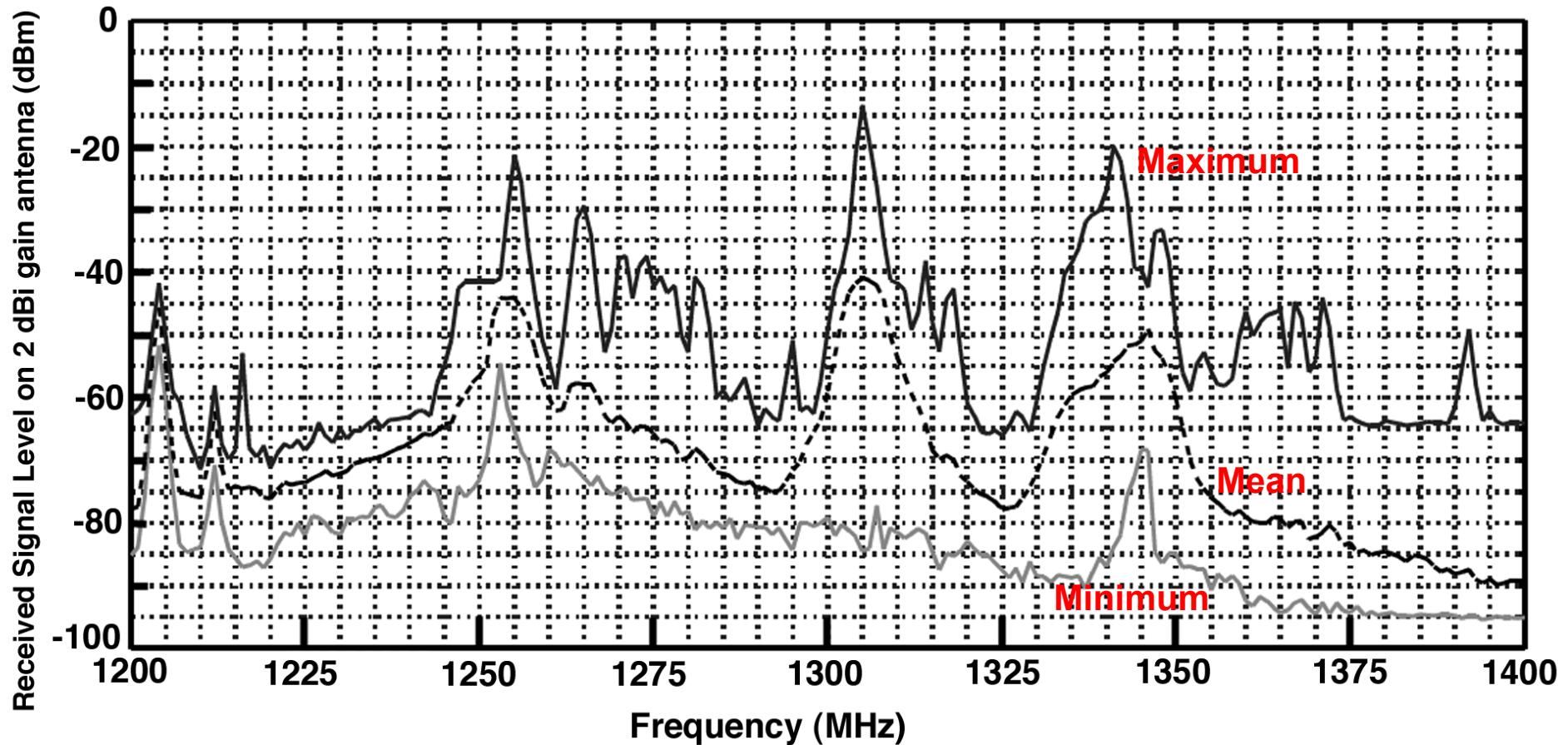
-Published NTIA spectrum surveys do show significant spectrum utilization by radars on an ongoing basis at every location in the US where such measurements have been done (for example, in Denver, San Diego, Los Angeles, and San Francisco).





Measured spectrum utilization of radars, continued

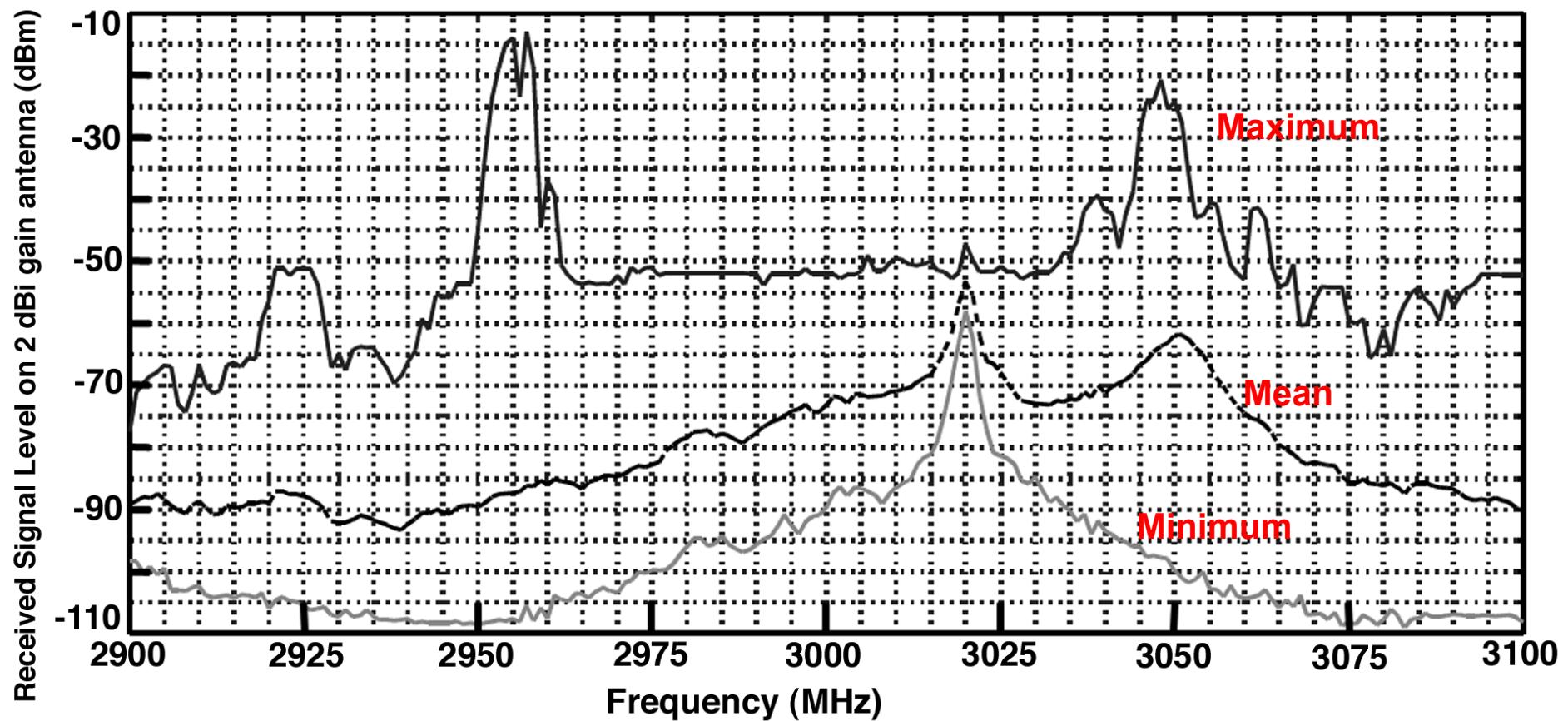
San Diego, California measured radar utilization of L-band





Measured spectrum utilization of radars, continued

San Diego, California measured radar utilization of C band





Measured spectrum utilization of radars, continued

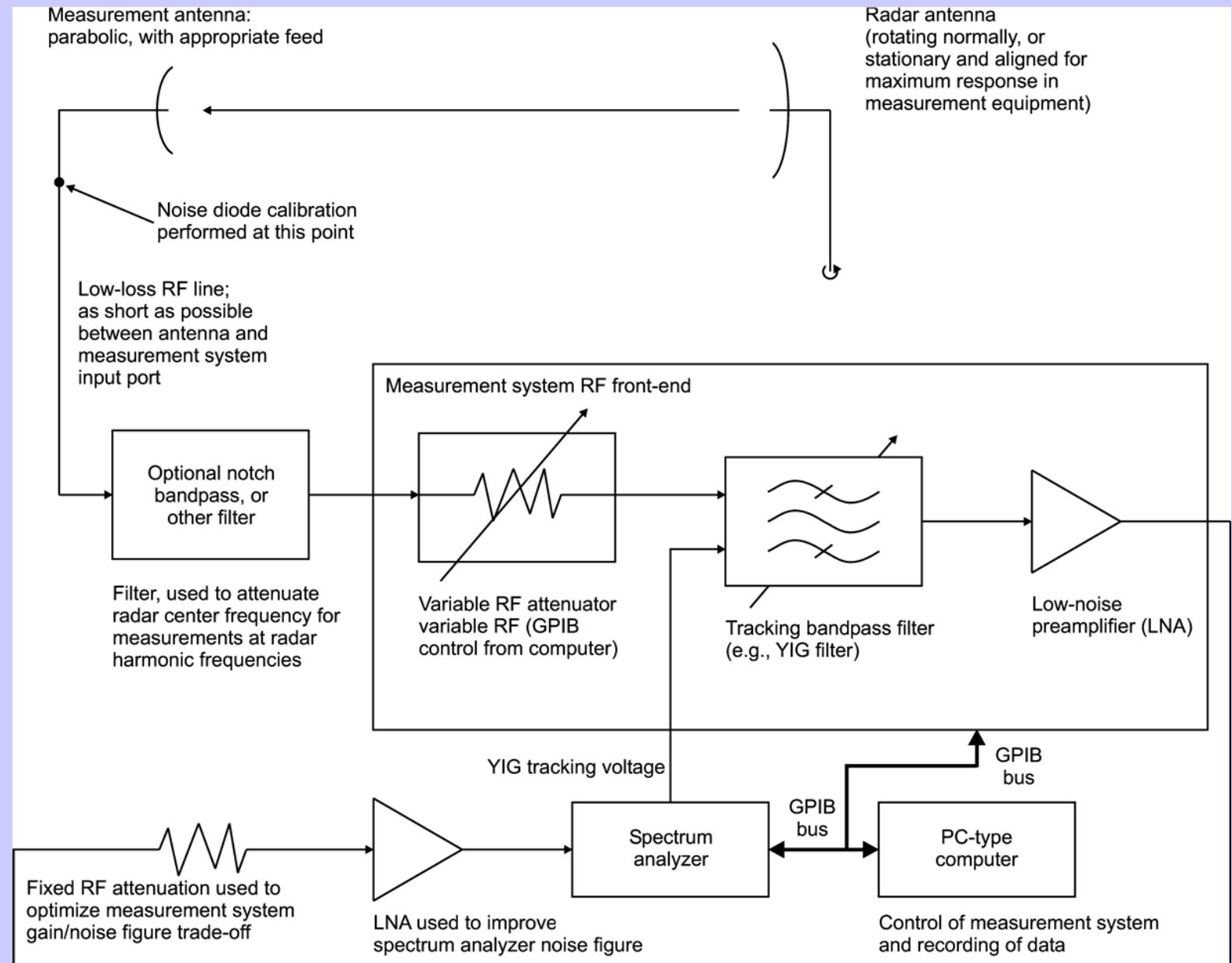
Why do some spectrum survey results not show significant usage by radars whereas the NTIA results do show substantial usage?

One likely reason is that radar emissions cannot be effectively observed with conventional swept-frequency techniques. Instead, radars need to be observed with stepped-frequency algorithms operated under computer control. NTIA spectrum survey reports and a recent NTIA Report on RSEC measurement procedures describe this methodology. See also ITU-R New Recommendation M.1177.

Wide dynamic range RF front ends with automatically controlled, tunable bandpass filter rejection are also needed. Many surveys do not include these algorithmic and hardware features.



NTIA radar meas. front-end





Radar receiver performance in the presence of interference

In NTIA studies that have been performed in support US Administration positions in ITU-R, radars have been intentionally subjected to low levels of interference from a variety of waveforms.

Protocols:

A radar selected for testing has its receiver disconnected from the antenna. In place of live target returns, test targets generated by NTIA hardware are injected into the radar receiver.

The power level of the targets is adjusted so that the probability of detection of these targets is as close as possible to 90% ($P_d=0.9$).

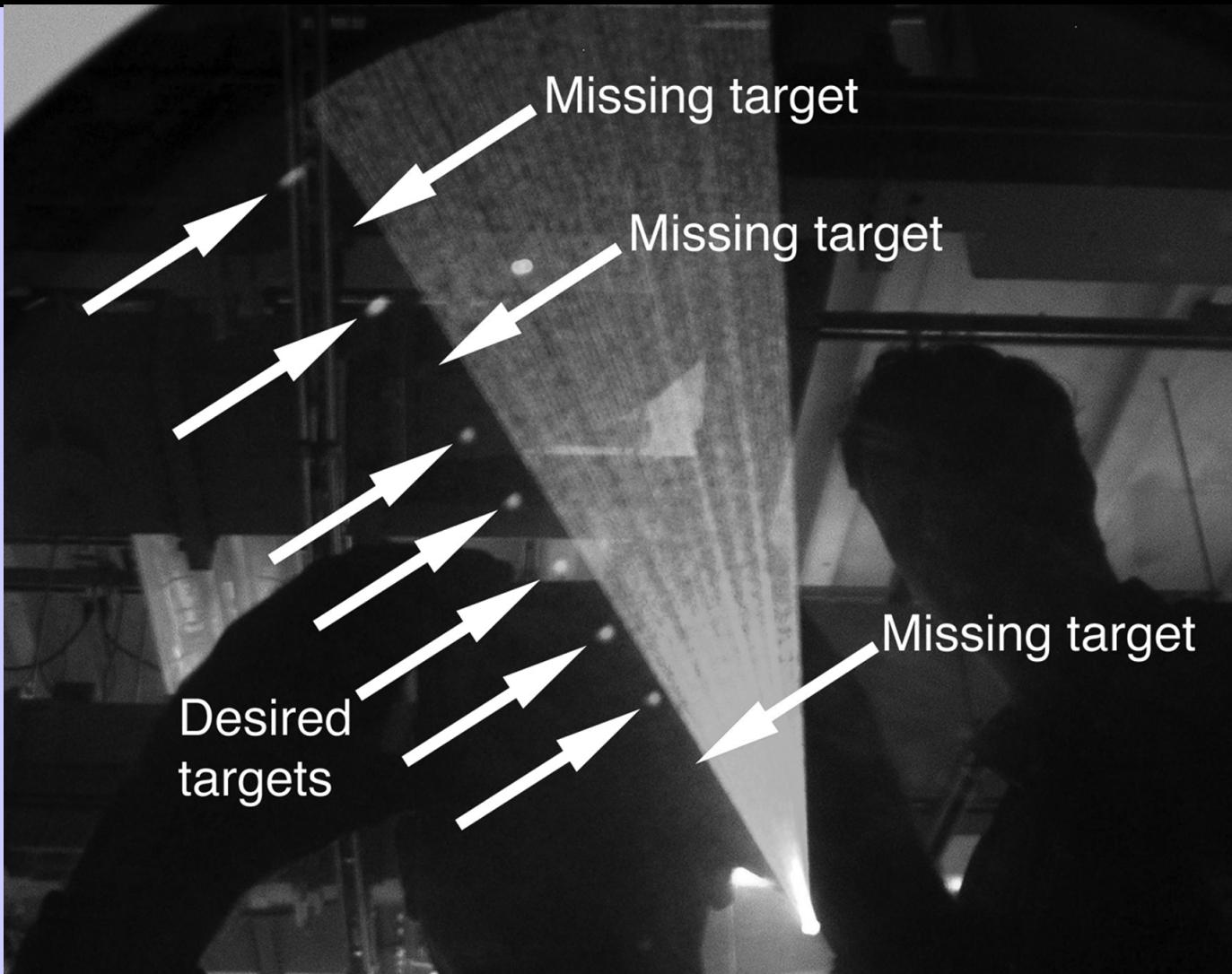
Interference is injected with a selected modulation. Target losses are counted as a function of interference power level relative to radar inherent receiver noise level (I/N).



Example radar plan position indicator (ppi) display during interference testing.

The bright wedge is a time-lapse effect of the radar ppi scan line.

Radar receiver performance in the presence of interference





Radar receiver performance in the presence of interference



Equipment room of a radar station

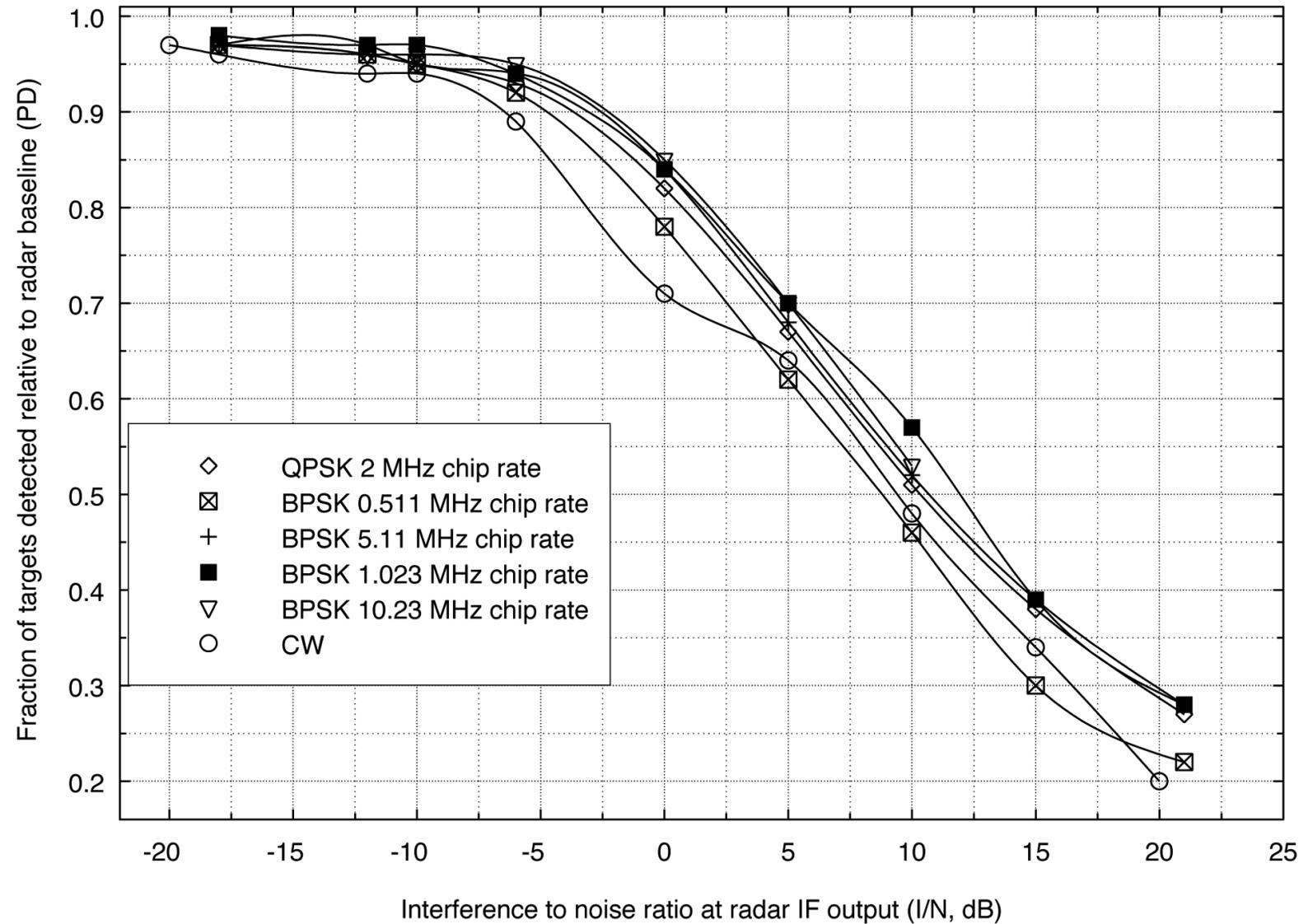


Examination of a radar receiver circuit card during interference testing



Radar receiver performance in the presence of interference

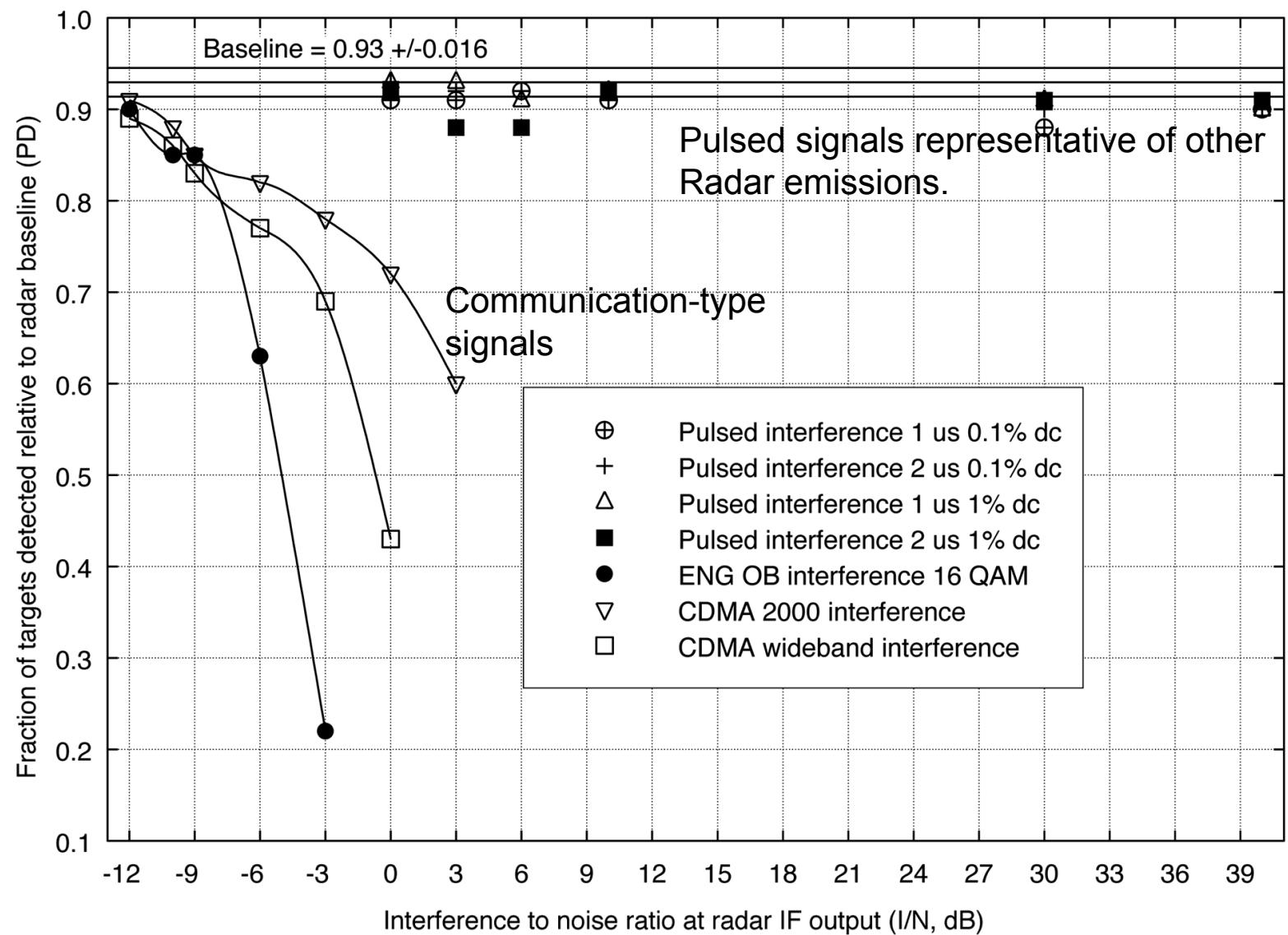
Example data showing target losses as a function of I/N ratio for a search radar.





Radar receiver performance in the presence of interference

Example data showing target losses as a function of I/N ratio for a maritime search radar.





Radar receiver performance in the presence of interference

I/N ratios at which measurable target losses begin to occur, based on results of measurements to date and grouped by radar mission.

Radar type	CW interference	QPSK interference	Pulsed interference
Air search	-10 dB	-10 dB	+30-40 dB
Maritime navigation and search	-10 dB	-10 dB	+30-40 dB
Weather surveillance	-12 dB	-12 dB	+30-40 dB



Radar receiver performance in the presence of interference

Do target losses only occur at the edge of radar coverage?

Interference at a given I/N ratio is observed to cause decreased probability of detection for targets that are within some number of dB (X) of radar inherent noise.

This condition for target loss is not dependent upon range, per se. To the extent that target returns (echoes) are weaker for more distant targets than for closer targets, losses in detection would correspond somewhat to target range. But target cross sections are not all equal...

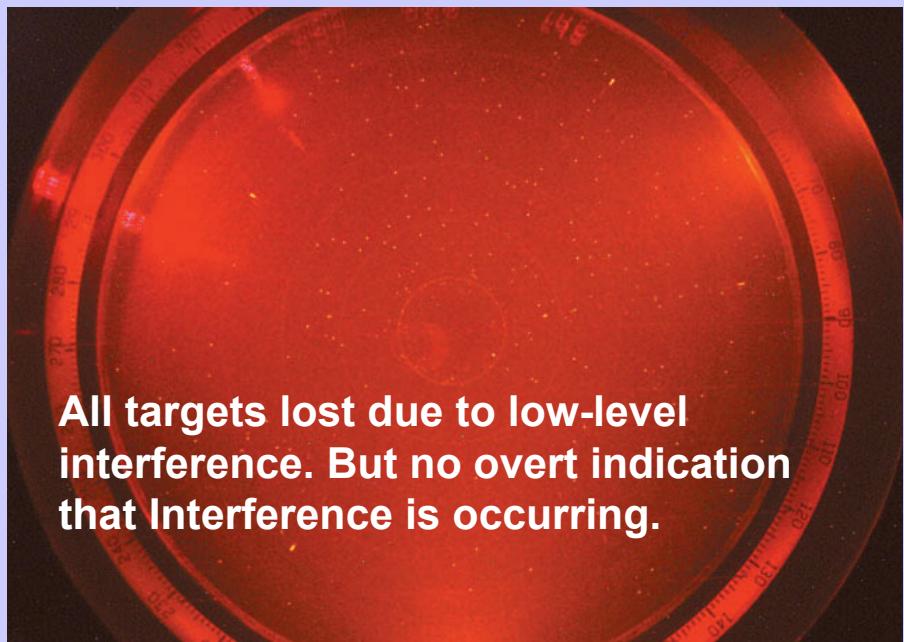
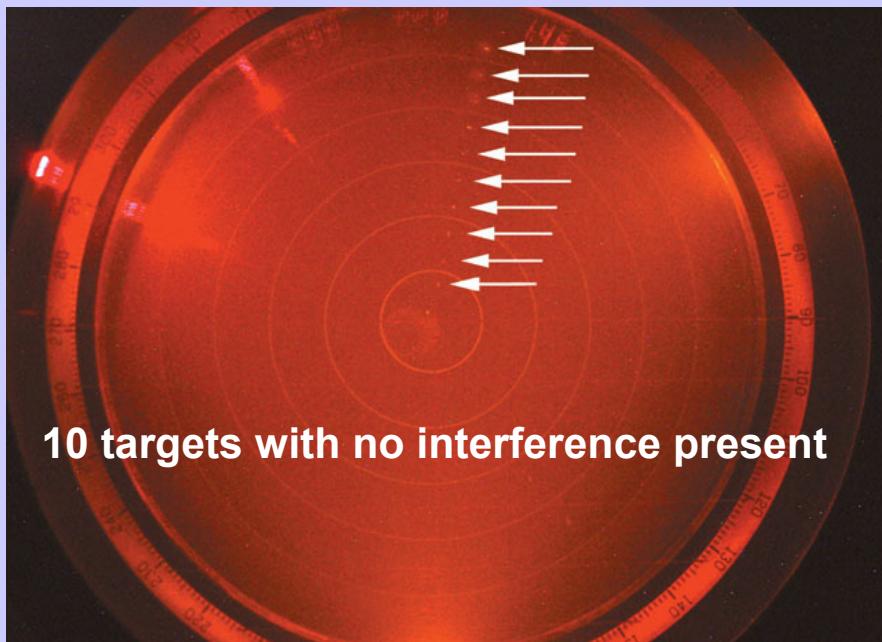
...some targets can be both weak and close. Therefore target losses cannot be translated into nothing more than range reduction. The possibility of loss of weak targets at close ranges does exist. Weak targets are not necessarily unimportant targets.



Radar receiver performance in the presence of interference

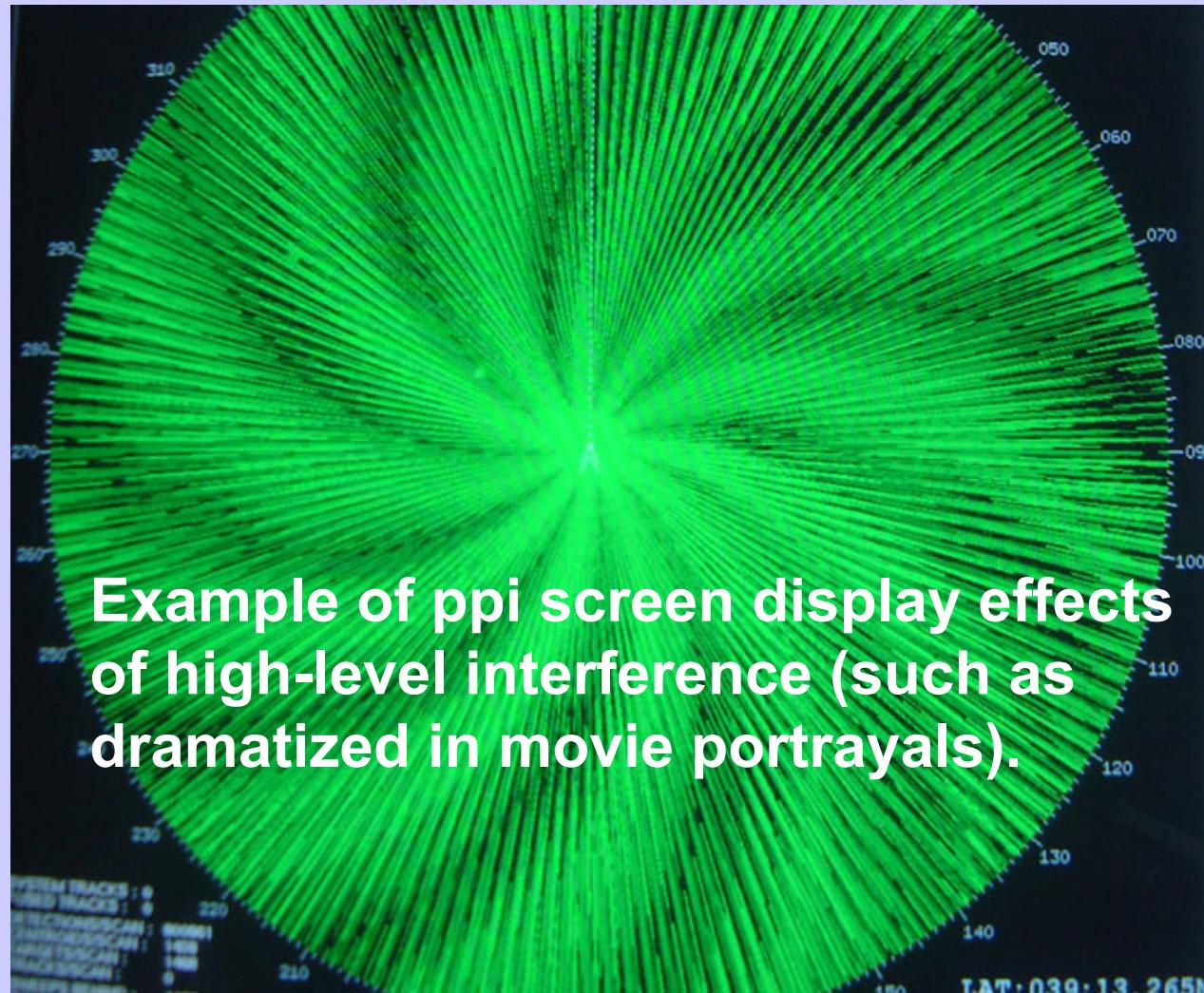
Target losses at low I/N levels of interference are insidious.

At low I/N levels, overt indications of interference do not seem to occur. Targets just fade out. Thus it is difficult to establish that such interference is occurring, and to what extent targets are being lost in this situation.





Radar receiver performance in the presence of interference





Technical consideration of a statistical basis for radar interference

Some Administrations in ITU-R are asking for consideration of an approach in which radar receivers experience interference for specified amounts of time at specified levels. This is called the ‘statistical approach.’

It has been argued by these Administrations that, since radars fail to detect targets at various times and for various reasons (such as, for example, from solar noise when the sun falls into the main beam of a search radar), then radar operations should be able to lose additional targets due to radio interference from intentional emissions.

This argument seeks to equate the impact and effects of environmental noise with possible impacts and effects of radio interference from intentional emissions.



Technical consideration of a statistical basis for radar interference

This approach raises at least two important questions:

- 1) How many targets may acceptably be lost under any given set of circumstances?
- 2) How can communication systems coordinate activities with radar operations to assess the rate at which targets are being lost at any given moment, and how can target losses be correlated with communication system operations?



Technical consideration of a statistical basis for radar interference

So far, no ITU Administration has identified criteria for acceptable loss of radar targets. It is difficult to know, *a priori*, whether any given radar target is sufficiently unimportant to not need to be observed and tracked.

Even if some criteria could be agreed upon, the technical requirement would exist for coordination of interference to radar receivers. Communication systems might have to somehow know where local radar operations are occurring and adjust operations accordingly. Or, radar sensors might have to know what targets are being lost due to interference, and have a way to communicate that information to the pertinent communication systems.

Such technical implementations are not anticipated in the near future.



Mitigation of interference by avoiding radar frequencies

This approach is called ‘dynamic frequency selection.’ The concept is for communication transmitters to sense radar signals (if any) on the communication systems’ frequency, and then move operations to another frequency to de-conflict the situation.

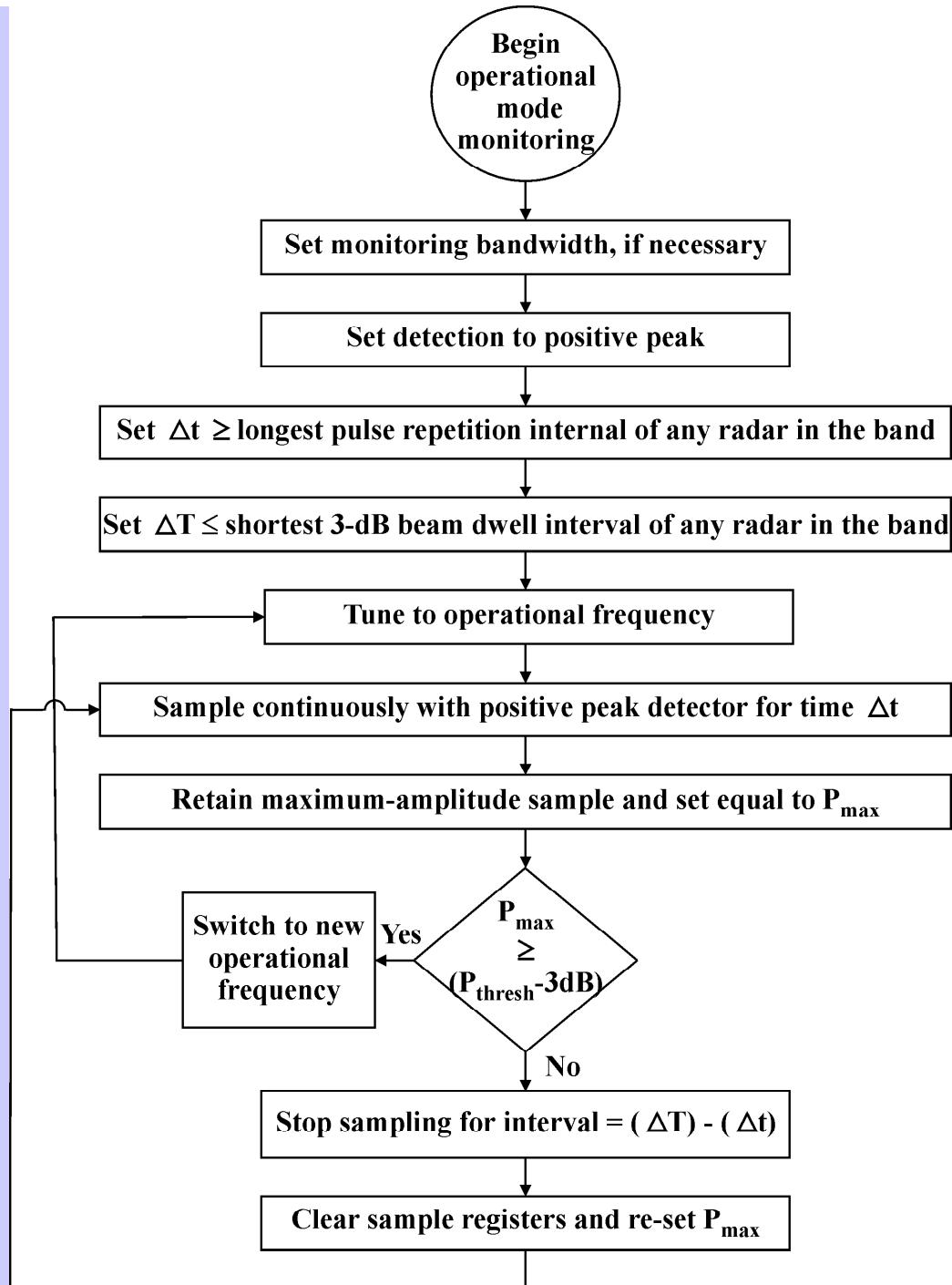
DFS depends upon the ability of a communication system to sense radar signals and then avoid/evacuate the conflicted frequencies.

No theoretical reason has been shown why this approach cannot work; it is possible in principle. But it needs to be tested.

NTIA, other Government agencies, and industry are currently working together to test this technology in the 5 GHz part of the spectrum in the US.



Representative example of an algorithm to listen for radar signals and avoid frequencies being used locally; other approaches can be used. But a significant fraction of time tends to be required to listen for radar signals.





Summary

- Radars are observed to significantly occupy their allocated spectrum bands, at least at surveyed locations in the US.
- In tests performed to date, radars have typically begun to lose targets in the presence of interference that is at an average level of about -10 dB I/N. (That is, at 10 dB average power *below* radar receiver inherent noise.)
- Effects of low-level interference are insidious because targets fade away without overt indications of interference on radar displays.
- Proposals to allow interference on a statistical basis are in a very early stage; the technical feasibility of this approach remains to be determined.
- An alternative approach, dynamic frequency selection, may be feasible. It requires substantial amounts of time for listening. The concept is undergoing tests at this time.