Control of Electric Field Radiation

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Historical Rationale

WWII era radio communications

Voice/cw communications in WWII

Radios had high input impedances because

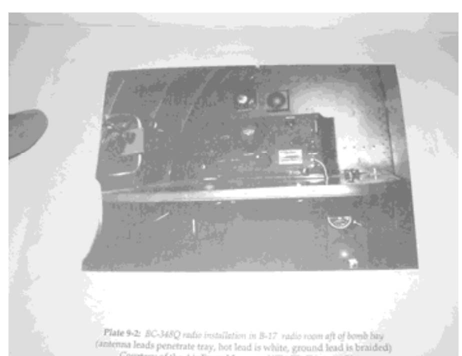
Antenna lead-in was high impedance and could not be loaded

A typical radio straddling what we now call MF and HF bands (0.15 - 18 MHz) was the BC-348

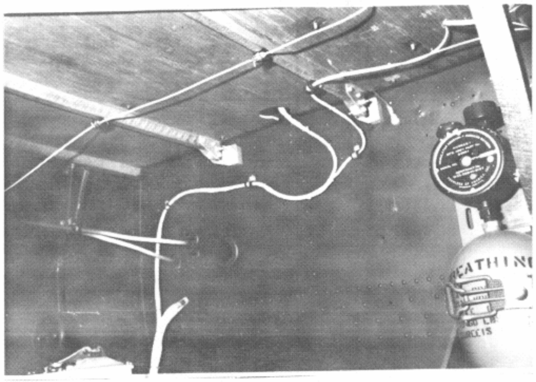
BC-348Q

BC-348Q was a sensitive receiver

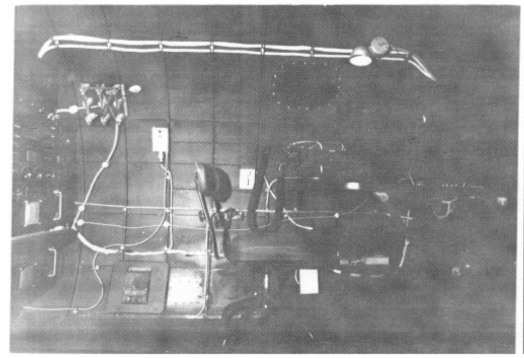
BC-348 rf input & installation caused rfi problems



BC-348 rf input & installation caused rfi problems



BC-348 rf input & installation caused rfi problems



Problem was recognized for what it was

(*b*) RADIATION COUPLING TO ANTENNA LEAD-INS.—Radio interference is coupled to antenna lead-ins by radiation when the lead-in is cut by any field radiated by a radio interference source or by wiring conducting radio interference. Because the all-metal fuselage effectively shields the lead-in from sources outside the fuselage, radiation coupling to the antenna lead-in occurs only from sources located inside the fuselage. The radiated radio interference fields inside the fuselage couple to the lead-in in the same manner as radio signals couple to an antenna.

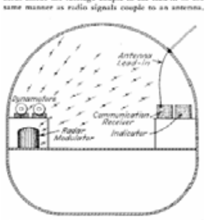


Figure 12—Coupling to Antenna Lead-in by Radiation

Excerpted from:
NAVAER 16-5Q-517
“Elimination of Radio Frequency Interference In Aircraft”
circa 1946

Problem Solution

Two-fold:

In the future, make the problem go away.

For the present (1950s - ‘60’s) impose radiated emission requirements that protect unshielded lead-in.

Problem Solution (cont.)

Make problem go away in future.

Excerpt from:
MIL-I-6181B Interference Limits, Tests and Design Requirements, 29 May 1953 Aircraft Electrical and Electronic Equipment

“3.2.5. Shielding antenna lead-in. - Equipments requiring antennas and not employing wave guides, shall be designed to utilize a shielded antenna lead-in.”

Protecting the unshielded antenna lead-in

Excerpt from NADC-EL-5515, rationale for MIL-I-6181B

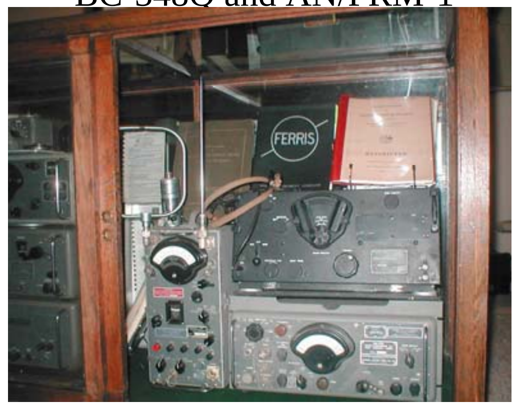
Experience has indicated that aircraft electronic equipments, which operate in the lower frequency ranges (0.15 to 20 mc), are more sensitive to the electric field because of the unshielded high impedance antenna lead-in, which has been in general use. Present practice is to control the electric field by radio interference measurements. This is done by utilizing a 41-inch rod antenna and treating any difficulties arising from equipments generating strong magnetic fields as special cases which require particular attention when the equipment is installed in the plane. Reference (e) requires that all equipment used with antennas be designed for use with a shielded antenna lead. If and when the unshielded antenna lead is completely eliminated from use in aircraft, a review of present methods and limits in the frequency range 0.15 to 20 mc will be required. Radio interference meters using the 41-inch rod antenna are so constructed and calibrated that they read directly the microvolts which are induced in the antenna by the interference field.

Protecting the unshielded antenna lead-in

Excerpt from NADC-EL-5515, rationale for MIL-I-6181B

A different situation exists for measurements made in the vhf and uhf ranges. Standing waves are usually present and interference fields, preponderantly electric or magnetic in nature, are seldom found at distances of 1 foot or greater. In addition, the antennas which are used are sensitive to a wide range of field impedances. For instance, a resonant dipole antenna has good sensitivity to low impedance (magnetic) fields near its center and high impedance (electric) fields near its ends. Other antennas, such as the discone, have a completely different distribution of impedance, polarization, physical size, and contour. Obviously, comparison of the effect of a given interference field upon the dipole and the same field on a discone can only be made in a very general manner. For this reason, in reference (e) radio interference limits are derived expressly for each particular antenna that is to be used, and exact correlation between different types of antennas is not expected. Practically all radio interference and field intensity instruments used in this frequency range are equipped with dipole antennas, and because it is the simplest antenna, with respect to determination of effective height and impedance, it has been taken as the standard antenna for the setting of radio interference limits. This means that if limits are to be derived for another type of antenna, comparative readings should be made with the new antenna placed in a radio interference field previously calibrated with a resonant dipole. Care must be taken that the antennas be located the same distance from the source and that the distance is that called for in the specification to be used. The antenna should also be oriented in the manner in which they are to be used, and the intensity of the field should be adjusted to induce a voltage in the dipole equal to the specification limit for which the correlation is made. If the polarization of the antennas being compared is different, the polarization of the radiating source should be arranged to be midway. The correlation should be made with different sources of signal and an average taken of the results.

BC-348Q and AN/PRM-1



Over the Ensuing Fifty Years

The last unshielded lead-in receivers were exhausted from the inventory in the mid-late 1960s.

Perhaps related, the test sample antenna separation increased from 1 foot (MIL-I-6181D - 1959) to 1 meter (MIL-STD-826 - 1964) and MIL-STD-462 (1967)

The rod antenna is still with us.

Tuned dipole range was reduced to 35 - 200 MHz with log spirals used above 200 MHz (-826) and finally the 137 cm biconical completely replaced the tuned dipole (-461).

Fifty Years After...

MIL-STD-461D/-462D (1993) replaced the log spirals with horns

MIL-STD-461F process is taking a hard look at the 41” rod.

But...

The real issue is that since the last of the unshielded lead-in receivers was replaced, the RE02/102 test method bears little resemblance to any platform installation. Hence the following -461E verbiage:

MIL-STD-461E RE102 rationale excerpts

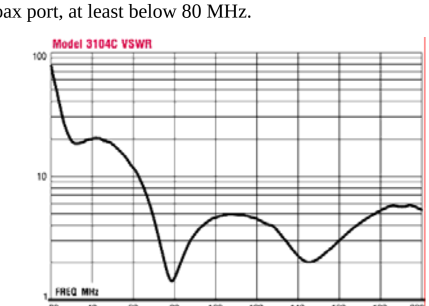
The limit curves are based on experience with platform-level problems with antenna-connected receivers and the amount of shielding typically between antennas and equipment and associated wiring.

These limits for the 30 to 400 MHz band, in particular, have been validated as being properly placed. It has become standard practice on some aircraft programs to use spectral analysis equipment wired to aircraft antennas to assess degradation due to radiated emissions from onboard equipment. Many problems due to out-of-limit conditions in this band have been demonstrated. It has also been determined that equipment meeting the limit generally does not cause problems. Most of this experience is on fighter size aircraft. The 20 dB/decade increase in the limit above 100 MHz is due to the aperture size of a tuned antenna ($G\lambda^2/(4\pi)$) decreasing with frequency. The coupled power level from an isotropic tuned antenna will remain constant. The curve breaks at 100 MHz because of difficulty with maintaining a tuned antenna due to increasing physical size and the lower likelihood of coupling to the antenna with longer wavelengths.

No limit is specified below 2 MHz for internal equipment on aircraft. There are antennas on some aircraft that operate below 2 MHz; however, these antennas are usually magnetic loops that have an electrostatic shield. These antennas have very short electrical lengths with respect to the wavelength of frequencies below 2 MHz and any electric field coupling will be inefficient.

Test Tips

This one courtesy of Don White - use a 10 dB pad at the biconical coax port, at least below 80 MHz.



Not exactly a Recommendation… An Observation

With a 12" test sample antenna separation, the direct ray was much stronger than a bounced ray.

With a 1 meter separation, that is not the case, hence the need for absorber.

But the -461E minimum absorber doesn't work well at low frequencies, especially in a larger room.

Here is an approach suggested by the work of Norm Wehling of Elite Electronics, from the 1993 ITEM.

Mode-stirring at low frequencies

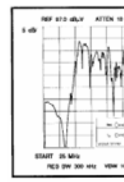


FIGURE 2. Field Intensity Variations.

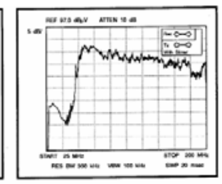


FIGURE 3. Field Intensity Variations with Paddle Wheel.

This only works with a max or peak hold function.

Troubleshooting Tip

(MOTO)

For the typical avionics enclosure, emissions below 400 MHz are almost guaranteed radiating from the cable harness. Don't sniff with a magnetic or electric field probe. Clamp a current probe around the bundle. If the cable is electrically long, scan the probe up and down the cable with analyzer in max hold mode.

Nine time out of ten, the profile from the cable is fairly similar to the RE scan.

Product fails RE102 and no fix in sight, or no palatable fix in sight.

Need to send out an SOS?

An SAS (spectrum analyzer survey) may provide some relief.

MIL-STD-464 excerpt:

"… Therefore, it is common practice to monitor all antenna-connected outputs with spectrum analysis equipment during an intra-system electromagnetic compatibility test. Analysis of received levels is necessary to determine the potential for degradation of a particular receiver."

MIL-STD-464 SAS cont.

An increasingly popular approach is to monitor antenna-induced signal levels with a spectrum analyzer. A preamplifier is usually necessary to improve the noise figure of the analyzer and obtain adequate sensitivity. The received levels can then be easily assessed for potential receiver degradation. This technique has been found to be very effective. Use of a spectrum analyzer is also helpful for RF compatibility assessment."