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Avionics & Portable Electronics: *Trouble in the Air?*

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There has been a growing concern relative to portable electronic devices (PEDs) aboard aircraft interfering with airborne electronics. This concern has been brought about because more devices are being carried aboard, they tend to be increasingly digital, and the clock speeds of these devices are steadily increasing.

PEDs include AM and FM radios, CD players, electronic games, and computers. There have been documented cases of harmful interference to navigation equipment due to these PEDs in air transport aircraft during flight. To date, there have been no incidents which resulted in injury or death that have been attributed to PEDs but the number of reports of interference is growing.

Although the incidents reported have covered all types of avionics systems some incidents such as errors in a gyrocompass have been difficult to explain. However, the particular problem appeared several times during a flight and was rectified each time by forcing passengers to turn off all electronic equipment. There are other cases where the explanation is quite clear. One such incident reported interference to a VOR receiver from a portable FM radio. In this case, the local oscillator of the typical FM radio fell directly in the VHF navigation band and was easily verified as being the source of interference.

With the steady increase in computer clock speeds, particularly the lap-top computer where clocks are well within the VHF spectrum, interference to VHF navigation reception from lap-top computers is also easily explained.

Electrical equipment has endured interference from other electrical devices since the very beginnings of electronics. Before the term "electronics" was coined and "radio" was the only game in town, interference to radio equipment was a serious problem. Even Marconi, the only radio station on the air in 1902 when he transmitted across the Atlantic, had to endure interference from nature in the form of atmospheric noise. When radio became a popular hobby in the first decade of this century, the radio amateurs, government and commercial stations all vied for the same portion of the radio spectrum and the control of interference became a hot topic. The answer was then, and still is today, government intervention.

Every electronic circuit that operates with alternating current radiates. With the exception of, maybe, flashlights, all electronic circuits radiate. The amount of radiation depends on the magnitude of the current involved, the size and shape of the wires conducting the current and the frequencies involved. When the radiation cannot be eliminated, it is contained using shielding which is to completely surround the offending circuits in a conductive enclosure.

Fortunately, most electronic devices do not have currents high enough or wires that make good antennas, and the amount of radiation is not high. Unfortunately, at higher frequencies, even short wires can become antennas and shielding is common in radio equipment not only to prevent energy from radiating but to prevent the egress of external energy into sensitive receivers. This process of preventing signals from egressing and ingressing is called electromagnetic compatibility, or EMC. An electronic device that does not meet half of the EMC requirement and has inadequate protection from the effects of external signals only, affects the operation of the device itself. In the case of inexpensive consumer items, the additional cost of reducing the susceptibility to interference may not be justified. However, since the other half of the EMC requirement (radiation) can cause degradation to other systems, it is necessary that all items be tested and certified to be compatible with other electronic systems regardless of cost.

There are two parts to EMS for aircraft equipment, too. Electronic systems should not be overly susceptible to electromagnetic radiation and equipment should not generate excessive radiation. Airborne systems such as autopilots, electronic engine instruments and flux gates are designed to be immune to radiation such as that experienced from airborne transmitters.

Radio navigation systems cannot be made totally immune to radiation as that is their very purpose in life, to receive weak electromagnetic fields from ground-based radio navaids. But, of course, the radio navigation system receives energy only on bands of frequencies that are set aside for airborne navigation and are protected from harmful interference. Well, not completely.

Any device that is a potential radiator, (the previous example of the flashlight is not a potential radiator), must be certified by the FCC, under part 15 of their rules, in order to be sold in the United States. As a preventative measure, the radio navigation frequency bands are set aside, in part

15, where no intentional radiation may take place. A garage door opener, a cellular telephone or a child's walkie-talkie are examples of intentional radiators and may not use navigation frequencies for their operation. If some device unintentionally radiates, such as the harmonic of a computer clock, there are specific limits placed on that radiation. Therefore, the radio navigation frequencies are protected in so far as the amount of radiation is limited. Just how much intensity of a part 15 certified device can be greater, when measured at 3 meters, than the guaranteed minimum field intensity within the service volume of navaid.

Another factor to consider is the field intensities for PEDs shown in the table are for FCC certified devices. These levels may not represent PEDs that are damaged, modified, or contain add-on devices or brought on board by an international traveler from another country.

TABLE 1

Service	Frequency Range	Minimum Level In Service Volume	Part 15 Limits for PEDs at 3 meters
VOR	108 MHz - 118 MHz	90 uV/m	150 uV/m
CAT 1 LOC	108 MHz - 112 MHz	40 uV/m	150 uV/m
MB	75 MHz	3,000 uV/m	100 uV/m
GS	328.6 - 335.4 MHz	400 uV/m	200 uV/m
DME	978 MHz - 1213 MHz	1,375 uV/m	500 uV/m
MLS	5031 MHz - 5091 MHz	237 uV/m	500 uV/m
GPS	1.5 GHz	48 uV/m	500 uV/m

radiation is permitted? And, how much damage could legal radiation cause?

Determining the maximum radiation permitted is simple. The radiation from a part 15 certified device is measured at a distance of three meters and the limits are specified as an electric field intensity as shown in Table 1 above. Electric field intensity varies inversely with distance, so at twice the distance (six meters), the maximum field intensity would be half that shown in Table 1.

Determining how much damage can be done to an avionics system is not as easy. As a first approximation, let us compare the field intensity of the interfering radiation to what would be encountered from a typical radio navaid.

A reasonable benchmark for setting the radio navaid field intensity is the minimum field intensity within a service volume as suggested by ICAO in annex 10. These intensities have been tabulated in Table 1 along with the maximum interference field intensities.

One glance at Table 1 shows the problem very clearly. The legal field Modified and damaged PEDs are common, such as a lap-top computer where the metalized paperboard shields got in the way when the computer was reassembled after installing an add-on device and were subsequently discarded. Since the computer worked just fine after reassembly, the shields were never missed!

Another factor to consider is that the field intensities for navaids shown in Table 1 are within the service volume. Aircraft often use radio navaids outside of a service volume. It is not as if there is a road sign that warns pilots they are leaving the service volume and to expect increased interference to their navaids.

Our immediate concern from Table 1 is from those interfering field intensities that are greater than the desired field intensities. This does not imply that as long as an interfering signal is less than the desired signal, our problems are over. In fact, weak interfering signals can be more problematic than strong signals.

When an interfering signal is very strong, the damage is significant. Interference to a VOR from a very

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strong computer clock would cause extreme errors, cause the flag to appear, and distort the audio. It would be very clear to the flight crew that something is wrong and to take necessary actions. On the other hand, a weak interfering signal is more likely to cause insidious errors that can go unnoticed for a long period of time. Some recent interference reports were aircraft that had been repeatedly contacted by air traffic control and quizzed as to why the aircraft could not seem to stay on course. It was found that a PED was causing an error of a few degrees to a VOR receiver. To the flight crew, the aircraft was flying a perfectly centered CDI while the aircraft was on the wrong radial.

Just how much stronger than the interfering signal the desired signal must be to insure that no significant interference will result is dependent on a large variety of factors. One such factor is the type of navaid involved. As an example let us consider the effects on a VOR signal to gain an understanding on how a VOR may experience small bearing errors as described in the previous example. There are two important modulations applied to a VOR carrier, the reference and the variable, which together, allow the VOR receiver to determine a VOR bearing. Both of these signals amplitude modulate the VOR RF carrier at 30 percent each. The signal intensities shown in Table 1 refer to the carrier intensity and the information that is sensitive to interference is in the sidebands which are 10 dB below the carrier. Clearly, if the interfering signal were the same amplitude as the information signal, this would be a clear case for alarm. What if the interfering signal were only 10 percent, down another 20 dB from the sidebands? It is not hard to imagine that small, insidious, errors could result from interfering signals that are as much as 30 dB below the carrier level of a VOR signal.

Some other factors affecting the nature of interference are the frequency and frequency stability of the interfering signal. It is ironic that a stable interfering signal, such as from a crystal-controlled computer clock, can cause more damage than an unstable signal. As an example, let us consider an interfering signal that was moderately weak but was 30 Hz above or below a VOR carrier frequency. This frequency difference would cause a 30 Hz heterodyne which will add to the 30 Hz VOR variable modulation and cause bearing errors without affecting the receiver's flag. A less stable interfering signal would cause random errors and effects which would tend to average out to zero.

Some interfering signals that have been sufficiently unstable as to not cause significant problems are becoming stabilized. As an example, the local oscillator for a portable FM radio, as previously mentioned, falls directly in the VHF navigation band making it a potentially serious problem. Most designs either have no frequency stabilization or rely on automatic frequency control, or AFC. Potential frequency drift of the oscillator is corrected by AFC by locking on to the received station. Over the long term, AFC is successful in stabilizing the local oscillator frequency, but in the short term, the oscillator frequency moves about quite a bit. Modern, more sophisticated designs use frequency synthesizers which can provide a very stable local oscillator, and consequently it becomes more of a threat as a spurious signal.

Passengers do use PEDs aboard aircraft and if the potential for trouble is as severe as it might appear, there must be a flood of reported problems. But this is not the case. There are factors that affect the possibility of interference. In the case of air transport aircraft, there are both mitigating and aggravating factors.

On the helpful side, the very size of air transport aircraft is a help in reducing the amount of interference from PEDs. The VHF NAV antenna is high on the vertical stabilizer and the glide slope antenna is far forward on the nose. This places quite a bit of distance between the PED and the antennas but not all of the antennas are so far away. Some directional SATCOM antennas are just above the first class cabin windows. Interference to communications would seem to be more of an annoyance than a danger. However, satellite communications for such important items as trans-oceanic route assignments and GPS differential corrections have been seriously considered.

On the down side, air transport aircraft have a lot of passengers dispersed about a big cabin. Even though the fuselage can offer some significant signal attenuation, there are hot spots within the cabin where if the right combination of PED, location, operating frequency, and antenna come together, there will be interference. The statistical probability of all the right factors coming together may be very small; but, when the fact that there are thousands of aircraft with hundreds of passengers each, every day, around the globe, the situation may be more probable than first realized.

In the case of smaller, general aviation aircraft, there is very little impediment to the interfering signal from a PED reaching a navigation antenna. Measurements made by this author show that fuselage attenuation for small aircraft, for all practical purposes, is zero. The field intensities for part 15 certification are based on a three-meter distance between the certified device and the measured field intensity. Three meters is longer than the distance between PEDs and NAV antennas in some small aircraft.

Many aircraft are being fitted with GPS receivers which are jam resistant, and thus, should be less susceptible to interference. Notice, GPS is *jam resistant*, not jam proof! GPS receivers operate with signal strengths, which in the classical sense, would be below the noise level. Although the GPS signals are noise-like, they are actually based on known sequences called pseudo-random noise. In the GPS receiver the satellite signal is separated from the true-random noise by a process called correlation. Like random noise, interfering signals will not correlate with GPS signals allowing the GPS signals to be extracted from interfering signals as well as noise. Interestingly, the most likely PED to interfere with a GPS receiver is a portable GPS! This is because the internal clocks of all GPS receivers are synchronized to the same satellites and defeats the advantages of correlation.

Is there any hope that on-board PEDs and avionics will ever co-exist? In the case of air-transport category aircraft, the problem is so complex that it will take an enormous effort and time to assure no loss of safety with PEDs aboard. A special committee of the RTCA, SC-177 was formed to investigate the problem and a report is due out in the near future. This is a very difficult problem to analyze and the report may not have a guaranteed fix.

In the case of small aircraft, the problem can actually be worse because of the proximity of the antennas to the PEDs. On the other hand, the flight crew is closer to the passengers and can have more control over what electronic devices will be used, providing the flight crew understands the potential problems. Small regional jets and commuter aircraft, may be the most dangerous situation of all. Often there are no cabin attendants to check for PED use and the proximity to the NAV antennas may be quite close. ❏