MUTUAL COUPLING OF THE ANTENNAS ON THE HELICOPTER TAIL

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For systems to interact, the frequencies have to be above a specified power threshold, and their spatial as well as their time domain characteristics have to be overlapping. When any EM wave transfers from one system to another the systems are said to be 'coupled'. This term is used for systems when this occurs unintentionally. At the design stage when positions of antennas are continually being changed, a quick and easy means of estimating the coupling between antennas is required. Computer modeling cannot be used at this stage, since the change of position of one antenna is invariably accompanied by the change of positions of a number of adjacent antennas, and a quick method of determining the impact is required. Additionally it is more satisfactory to perform calculations since the coupling has to be estimated over large combinations of antennas at the design stage, and a spreadsheet is more amenable to the frequent changes that occur during the design stages of a new aircraft or complete systems modification of an existing aircraft.

K e y w o r d s: model, helicopter, coupling, wireless transmission, interoperability

1 INTRODUCTION

The term RF interoperability is used for operability between systems, whereas the term intra-operability is used for operability within a system, for example between the different LRUs or entities within the same system. Intra-operability will not be addressed in this article. It is a matter for the manufacturer and/or supplier of the system. It is possible for individual LRUs to meet the EMH standards for emissions as well as susceptibility, but then when all the LRUs are connected up together, the total system could fail the standards. This is because the phases of the emissions could result in their combining to give a resultant that is above the amplitude of the individual emissions. These are commonly referred to as 'inter-modulation cross-products'.[1]

2 COUPLING BETWEEN SYSTEMS ON AN AIRCRAFT

The coupling could be due to EM emissions resulting from a combination of conducted and radiated emissions and between a transmitter and a receiver, and could be due to both being inside the airframe, both being outside the airframe, or if they are on opposite sides (one inside and one outside) of the airframe. There is a very fine dividing line between conducted signals that couple capacitatively (or inductively) between physically unconnected circuits, and radiated signals in the near field of the source. However, if the distances involved are very small in terms of wavelengths (of the order of one-thousandth or so) the mechanism of energy transfer can be considered to be induction, whereas for larger distances the mechanism of transfer is through radiation, and the energy is characterized in terms of electric and magnetic fields rather than in terms of voltages and currents.[1]

2.1 Conducted Emissions inside the Airframe

The airframe of an aircraft usually consists of a frame made up of hollow rods (called ribs) that run longitudinally from the nose to the tail of the fuselage and are held in place by circular rings called frames as shown in Figure 1. The frames usually also have holes in them (as shown in the first part of the figure) to reduce the weight and this also allows cables, pipes, and so on to traverse the length of the aircraft between the outer skin and cabin walls. Inside the airframe there may be instances where the RF cables from the transmitter and receiver (to the respective antennas) are adjacent to each other as shown in Figure 3. This would occur because the cables (RF as well as mains power) are tied together in looms and then run between the cabin wall and outer skin. Thus, for instance, if the transmitter is on the wall of the cabin midway between the floor and ceiling of the fuselage, the RF cable to the antenna could be taken down to floor level and then strapped together in a loom that runs along the circumference of the fuselage to the antenna at the top. The RF cable from the receive antenna of another system could also be strapped into this same loom. Although in theory this should be avoided for systems within the same frequency band, this may not be viable or implemented in practice. Coupling through induced currents would occur and the integration team would then try and minimize the problem by EM shielding of cables.[1]

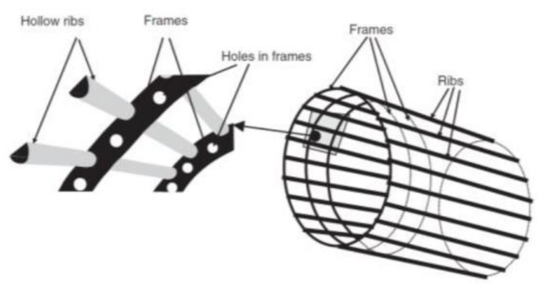

Figure 1- Fuselage of an aircraft showing the ribs and frames

The term pick-up is used if the interfering source is power (400 Hz for aircraft) and the term cross-talk is used when the actual signal from one cable can be retrieved by another unconnected cable. Double or even triple shielding on cables would be used in preference to rerouting of the cables.

Figure 2- Fuselage of an aircraft Boeing 777 showing the ribs and frames

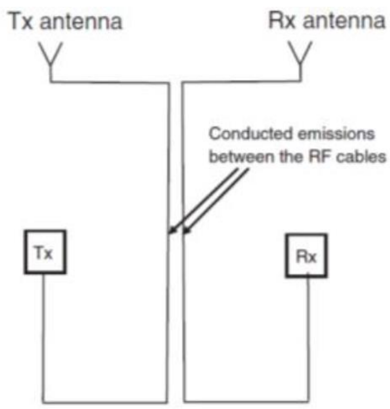

Figure 3- Side view of schematic of a receiver system subjected to conducted emissions from a transmitting system

2.2 Radiated Emissions inside the Airframe

The connectors attached to the RF cables may also have apertures through which radiation is emitted. In order to reduce this the connectors would have ‘back shells’. There may also be apertures in the equipment LRUs that would be used for ventilation. If the frequency of the equipment is high even small apertures can result in EM radiation being emitted through them, because the wavelength is short. This radiated emission could then enter the LRU of a ‘victim’ system and cause interference. The victim system would be said to be ‘susceptible’ to EM interference.

2.3 Radiated Emissions outside the Airframe

Radiated emissions outside the airframe would occur between the transmit antenna of one system and the receive antenna of another system. These would also constitute unwanted and unintentional coupling between the systems. Since we are only dealing with emissions with respect to interoperability between on-board systems, we do not need to consider any emissions emanating from off-board systems such as from the ground, satellite or other aircraft. Radiated emissions outside the airframe form part of the antenna sitting process, whereas radiated and conducted emissions within the airframe (as well as conducted emissions through the airframe) are part of the EMH integration process.

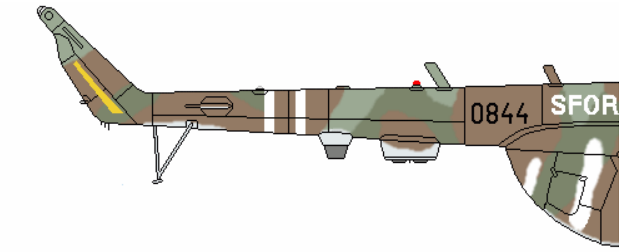

Figure 4- Antennas on helicopters tail

2.4 Radiated Emissions through the Airframe

These are a result, for instance, of:

1. emissions emanating from an LRU, RF cable or RF connector inside the airframe being radiated through a window, or other non-metallic part of the airframe and being incident on the antenna of another system,
2. emissions emanating from an antenna outside the airframe entering the inside of the aircraft through a non-metallic part of the airframe and coupling to the LRU of another system.

Levels of radiated emissions are difficult to measure accurately with respect to specific positions and measurements would normally be performed with a probe connected to a receiver on peak hold so that only the maximum level is obtained. Peak detectors are used in measurements for compliance with military standards such as MIL-STD 462, whereas quasi-peak detectors are recommended by bodies such as Comit´e International Special des Perturbations Radio electriques (CISPR), for compliance with national standards and legal regulations.[1]

2.5 Conducted Emissions outside the Airframe

The conducted emissions outside the airframe are those resulting from a transmit antenna and a receive antenna sharing the same ground plane. This reduces the isolation between the antennas resulting from their spatial distance apart. However, this coupling due to conducted emissions through the common ground plane is usually very small and a secondorder effect. The isolation between two line of sight (LOS) antennas calculated using the formula for radiated emissions gives values fairly close to those measured, indicating that the coupling through the common ground plane does not have any significant effect.[1]

2.6 Conducted Emissions through the Airframe

Conducted emissions through the airframe (either from the outside to inside or vice versa) could occur at low frequencies, for instance, if the HF system is transmitting. At these low frequencies, when the HF antenna is radiating, the whole airframe will have currents induced in it and the EM waves would be conducted through the airframe and may couple to RF cables and hence cause interference to systems inside the airframe. Conducted emissions from inside the airframe to the outside are likely to be of a low level and hence are unlikely to be a major problem.

2.7 Coupling between Systems due to Radiated Emissions outside the Airframe

This is the only part of coupling between systems that is within the scope of the antenna integration team. The simplified coupling mechanisms between a transmitting system and a receiving system due to radiated emissions are depicted schematically in the Venn diagram of Figure 4. The frequency domain applies to frequencies at a threshold level that is likely to result in malfunction of the receiving system. The problems occur when all three domains (time, frequency and spatial) of a transmitter and receiver overlap.

If they just overlap in two domains, then there should not be a problem. For instance, if they overlap in the spatial and frequency domains, but not in the time domain, that is,

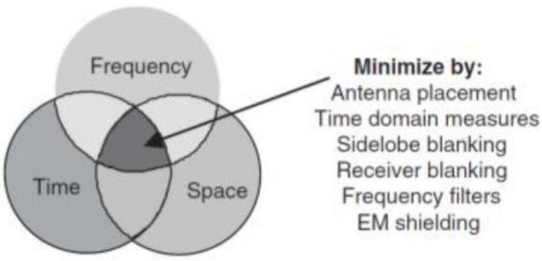

Figure 5- Techniques (with respect to radiated emissions) for achieving RF interoperability between a Tx and Rx system.

if the transmitter and receiver are spatially near but are not in the same time domain (i.e. not operating at the same time), no problem exists.[1]

Similarly, if they overlap in the time and frequency domains, but not in the spatial domain, then there will be no coupling between systems. If the signals from one system arrive when the susceptible receiver of a second system is operational, but the two systems are spatially separated or operating in different angular sectors (e.g. upper and lower hemispheres or directional antennas pointing in non-overlapping areas) so that the radiation from the transmit antenna is not incident on the receive antenna, then there will not be any adverse effect on the second system.

If they overlap in the time and spatial domains, but not in the frequency domain, then there will be no coupling between systems, since it means that they are separated in the frequency domain, that is, their frequency bands do not overlap. Of course, what must be borne in mind is that when we refer to the frequency band of a system, we are referring to its entire power frequency spectrum, and not just its carrier or fundamental frequency. Thus we have to consider the actual signal emitted. This signal (in the time domain) is converted to the frequency spectrum by using the Fourier transform. The frequency spectrum (i.e. the amplitude at each frequency) can be measured using a spectrum analyser.

3 TECHNIQUES FOR ACHVIEVING RF INTEROPERABILITY

As mentioned earlier, the final antenna layout is determined before all the systems parameters are known and by trade-offs between all the relevant disciplines. Thus measures usually have to be applied when the antennas and other system LRUs are physically installed. Techniques (with respect to radiated emissions) for achieving RF interoperability between systems as depicted in the Venn diagram of Figure 4 are:

1. antenna placement,
2. time domain measures,
3. sidelobe blanking,
4. receiver blanking,
5. frequency filters,
6. EM shielding.

In the case of the frequency domain it should be noted that the amplitude at the different frequencies is important. If the amplitude of the wave at a particular frequency is very low then the impact on the victim/receiving system will be negligible. In the case of electromagnetic interference (EMI) the standards define the level at each frequency or frequency band. In the case of RF interoperability the level will depend on the characteristics of the entire victim system.[1]

4.1 Antenna placement

The isolation between antennas can be increased by increasing their spatial separation. As mentioned in Chapter 3, antenna locations are low in the pecking order of the various disciplines. Thus the positions will be optimized by judicious application of trade-offs based on the other constraints. The initial antenna layout is based on perhaps placing the antennas 3 or 4 wavelengths apart at the lowest frequency in the band. This cannot be achieved at the low end of the VHF band for most aircraft, since at 30MHz the wavelength is 10 m. In the HF band no attempt would be made to attain this separation. Furthermore, the coupling between systems cannot be calculated since the details required are not available until much later in the system design process. These details include the powers transmitted, losses in the cables, sensitivities of the receivers, and so on. However, the antenna specialist is left with the task of predicting the coupling with the designated antenna locations. Once the positions of the antennas are determined it is very difficult if not impossible to change them if it is found that the isolation between the systems is insufficient from the interoperability point of view. This could be due to the necessary compromises caused by the dearth of real estate available, initially assumed power transmitted by the offending systems being higher and/or the victim system having greater sensitivity, incorrect losses assumed in the RF cables, etc. Higher losses in the RF cables will decrease the coupling between the systems and hence be advantageous (to interoperability), although this is not desirable for the operation of the system.[1]

4.2 Time domain measures

Time domain measures are used to ensure that the two conflicting systems do not transmitor receive at the same time. This can be accomplished by:

1. interleaving emissions,
2. manually suppressing (the transmitter or receiver),
3. press to transmit, where a manual switch is depressed so that when the offending system is transmitting the receiver of the victim system is automatically switched off.

Emissions can be interleaved whether they are CW or pulsed transmissions, although the term interleaving is usually only used for pulses. Thus, or instance, the transmission scan be restricted so that the different systems transmit in allocated time frames. Pulsed systems that transmit several pulses per second can stagger the pulses and allow pulses of another system to transmit within the same time frame, but not at the same instant in time. For some systems such as radar the interleaving of pulses can be undertaken easily, but other systems such as transponders (for ATC) that have to operate when interrogated, this may be impossible to achieve.

4.3 Sidelobe blanking

In this case the receiver is prevented from functioning by either manually or automatically suppressing it. The receiver can be blanked by:

1. manual means
2. programming
3. automatic means.

4.4 EM shielding

EM shielding is used to exclude or confine EM waves. Its increasing importance is in part due to the failure of many manufacturers to consult EM compatibility specialists at the design stage, and then attempting to shield equipment at the production stage to comply with the relevant standards. In the case of radiated emissions outside the airframe, shielding would most probably only be used to shield the HF tuner embedded in the mast of a towel rail mounted on the surface of the airframe.

The extent to which a material performs this function is referred to as its shielding effectiveness (SE). The SE of a material is the attenuation it presents to an electromagnetic wave and is defined as the insertion loss in dB obtained in the presence of the material. Solid materials prevent the penetration of electric and magnetic fields by three mechanisms:
1. reflection at the air–material interfaces
2. absorption as the fields travel through the material
3. multiple internal reflections (MR) at the material–air interface

The shield should be grounded, and if made of aluminium it should not be anodized. Anodizing makes the aluminium non-conducting so that it cannot be used as a ground.[1]

CONCLUSION

In this article, coupling between antenna systems was described. It briefly indcluded information about different possible ways of coupling inside, through and outside of an airframe. Then the article dealt with techniques for achvieving rf interoperability.

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