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Intermodulation Distortion in Metal Space Frame Radomes

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The Intermodulation Distortion phenomena

Large reflector antennas and metal space frame (MSF) radomes are fabricated from many panels and beams interconnected at joints with bolts and rivets. The contact at these junctions is not perfect and tiny gaps of air with the size of 10-100 angstroms are generated. These tiny gaps are filled, as time is passing, by metal oxide and metal-insulator-metal (MIM) junctions are generated. The MIM junctions constitute nonlinear circuit elements, due to the electron tunneling effect [1], [2] through the thin insulator gap, such that if illuminated by high RF power levels (larger than 10 mW/cm^2) they generate spurious signals. The electron tunneling effect is non-existent if the gaps are out of the range of 10-100 angstroms. These nonlinear elements give rise to intermodulation products (IMP) signals above the receiver noise level, when subject to high-power microwave radiation by two or more transmitters used simultaneously at different frequencies, f_1 and f_2. In radar and satellite transceiver systems, the close proximity of the transmit and receive bands cause the intermodulation products (IMP) of certain transmitted frequencies to fall within the receive band. The 3rd order product, ($2f_1$-f_2) being the highest level is of most concern, however, higher order products may also be troublesome depending on transmit power levels, receiver sensitivities and frequencies employed. These transmission generated IMP signals contaminate the receive band and may seriously degrade the signal to noise capability of the receiver.

The effect of the IMP in radar systems was first identified during the early 1940's on systems with antennas that had rusty bolts, particularly antennas on ships at sea. At that time it was referred as the "rusty bolt" phenomenon. They did not really realize what it was at that time, but they knew that if they prevented the bolts from rusting the IMP in the receiving system would be brought under control. The remedies proposed to reduce the IMP effect in such systems are:

- Cover suspicious junctures with highly conductive metal tape.
- Weld wherever possible to increase conductivity across possible air gaps.

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- Use insulators with thickness larger than 100 angstroms to avoid the electron tunneling effect.

The IMP Effect in Metal Space Frame Radomes

IMP signal level is an overall system design problem starting with the most fundamental consideration of the frequency spectrum allocations of the transmit and receive bands. If the frequencies and separations are properly chosen, IMP generation can be expected to be below practical system noise levels and out of the receiving band. In a MSF radome enclosed antenna system there are many contributors to IMP, like:

- Waveguide feed horn
- Subreflector
- Main reflector
- The MSF radome

In a well designed system the system engineer is well aware of the various contributions and the IMP power levels should be more than 200 dB below the level of the transmitted carriers in order to be discarded. In many cases the IMP effect of the radome is negligible compared to the other sources. ESSCO is fully aware of the components and characteristics of the MSF radome that can be a source for generating IMP signals. During the last years, various methods to eliminate the generated IMP have been investigated and implemented in ESSCO MSF radomes, like:

- Separation of the MSF beams by insulating material
- Use of plastic sleeves and washers to isolate the radome hardware (bolts and nuts)
- Use of nylon nuts
- Special care of workmanship and cleanliness of manufacture to avoid sharp metal edges, micro-cracks in metal surfaces, metal scratches, metal burrs, not perfect welding and impurities in plating.

Fig. 1 shows a typical comparison between the measured 3rd order IMP signal levels of a standard MSF radome and a special ESSCO treated MSF radome. The test data was acquired for two transmitting frequencies f_1 and f_2 illuminating the radome's junctions with power levels of $300\ mW/cm^2$.

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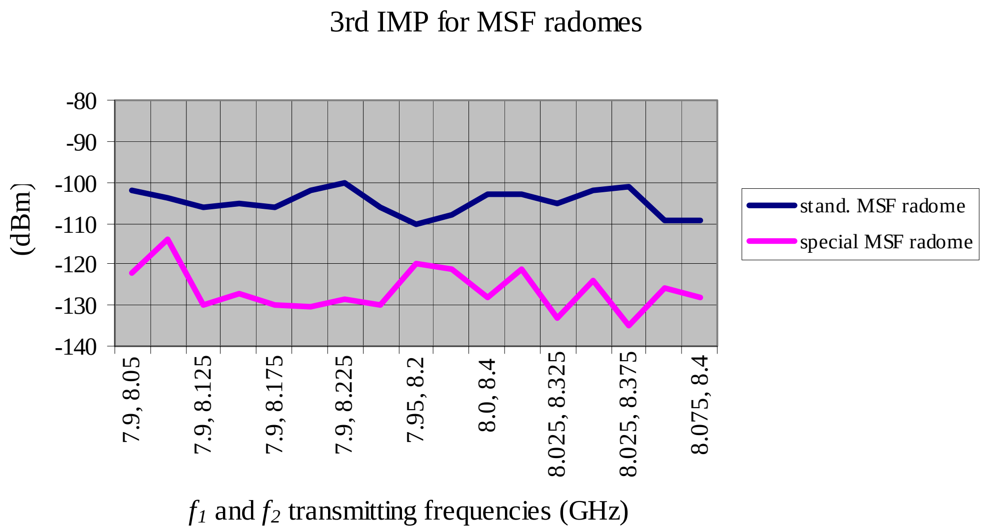

Fig. 1-3rd IMP signals power levels for a standard MSF radome and a special treated MSF radome.

One can observe that a reduction of up to 30 dB in the IMP distortion can be obtained using ESSCO's proprietary treatment of the MSF radome.

An important method to measure the level and source origin of the IMP signals is the RF imaging technique [3]. Using this method the IMP signals are measured in the near-field of the radome junction and are back projected on a plane crossing the problematic junctions and panels. This process enables to locate the suspicious regions, which generate IMP signals and treat them appropriately. However, imaging has its limitations in terms of ultimate resolution that can be obtained $\approx\lambda/2$.

Conclusions

IMP signal generation is a significant problem that needs to be addressed especially in high power Transceiver systems. This phenomenon limits the dynamic range of the system if it is not addressed appropriately. The first step in tackling the problem is careful spectrum management to minimize the amount of IMP distortion in the receiving band. The next step would be careful design of the antenna to minimize as much as possible any MIM junctions, by bridging air gaps with conductive tape or alternatively increasing insulation of problematic junctions using low loss dielectric materials. Finally, if necessary ESSCO can specially treat the MSF radome to reduce the IMP signal level generation due to the radome. This special treatment may reduce

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the IMP power level by 30 dB compared to the IMP power level generated by a standard MSF radome. This IMP level is negligible compared to all other IMP sources in the system.

References

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