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CEPT ECC
Electronic Communications Committee

WG SE 7

Brussel, 17-18.April.2019

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Source: DFS (Germany)

Subject: Increase in pulse-width, pulse-count and -aggregate duty cycle due to multipath and signal strength variation

Group membership required to read? (Y/N) N

Summary:

For any receiver with circuits that are intended to reduce the interference due to echos of aeronautical pulses generated by multipath, the magnitude of interference generated by multipath needs to be understood. With signal strength and multipath the pulse width and/or pulse count will increase.

While DME and TACAN pulses are normally depicted in literature to have only a width of 3.5 µs ±0.5 µs, this is only true at the 50 % amplitude points of the pulses. Below the 50% amplitude points width will increase to 8 µs or more.

Longitudal- and or lateral-echos/-multipath can occur at most locations, especially since aeronautical pulses, e.g. from DME and TACAN, can be stronger than -40 dBm SE7(19)176. Multipath can increase the pulse-width, or increase the number of pulses received above receiver thresholds.

In extreme cases pulse trains that originate from a single interrogation pulse pair due to multiple echoes with a decreasing signal strength, will occur. Such pulse trains have been measured to last for 150 µs or longer. DME and TACAN transponder receiver are therefore equipped with Short- and Long-Distance Echo-Suppression circuits (SEDS and LDES) which can provide protection for up to 350 µs after the initial interrogation pulse pair was received.

Proposal:

SE7 is invited to note and include in the PMSE sharing report this information as Annex e.g. in chapter 3 propagation.

That strong aeronautical pulses, e.g. from DME and TACAN, can produce multipath echoes at most locations. Due to the large measured signal strength that can exceed -40 dBm SE7(19)176 multipath echoes will be well above receiver threshold and increase

- pulse width beyond the 3.5 µs ±0.5 µs specified for the 50% amplitude points
- the number of pulses received and in extreme provide a continuous train of pulses with decaying strength for 150 µs or more.
- the aggregate duty cycle

Background:

Increase in pulse-width, pulse-count and -aggregate duty cycle due to multipath and signal strength variation

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CEPT WG SE-7 Brussel 17 – 18.April 2019

Summary

For circuits that reduce the interference generated e.g. of echos generated by multipath the variation of pulse width with signal strength and various multipath effects need to be taken into account.

While DME and TACAN pulses are normally assumed to have a width of 3.5 µs ±0.5 µs, this width is only correct for the 50 % amplitude points. Below the 50 % points pulse width will increase to 8 µs or more.

With increasing signal strength the stronger multipath longitudal- and or lateral-echos generated by pulses of aeronautical systems, e.g. DME and TACAN, need to be considered as interference. In presence of short distance multipath (duration of pulse pair) pulse's width or amplitude can increase when pulse and echo(s) overlap constructively. Long distance multipath will increase the number of pulses received and in consequence the aggregate duty cycle increases. In extreme cases pulse trains consisting of many echoes with a decreasing signal strength, that originate from a single interrogation pulse pair have been measured to exceed 150 µs. For echo suppression DME and TACAN are equipped with Short- and Long-Distance Echo-Suppression circuits (SEDS and LDES) functional up to 350 µs after the initial pulse pair was received.

Increase of DME and TACAN pulse width with amplitude and pulse form

While aeronautical pulses, e.g. DME/N and TACAN, are depicted as Gauss shaped pulses in ICAO Annex 10 and other literature, this figures are only used to depict pulse-width, -droop, -rise- and -decay-time between the 10% to 90% amplitude points.

The definitions for DME and TACAN pulses are:

- pulse-width of 3.5 µs ±0.5 µs at 50% amplitude points.
- max. pulse rise time between 10% and 90%
- max. pulse decay time between 90% and 10% amplitude points
- pulse droop not to fall below >95 % amplitude
- and indirectly limitation by definition of max. absolute transmitted power of
  - 200 mW measured in 500 kHz centered ±0.8 MHz above and below fc and
  - 2 mW measured in 500 kHz centered ±2.0 MHz above and below fc

Below the -10 dB points even a Gauss pulse will widen as shown in measurements below. Manufactures are free to implement any waveform that meets the above criteria. The messured equipment are all fully ICAO compliant, and are the result of different interrogator designs and technology.

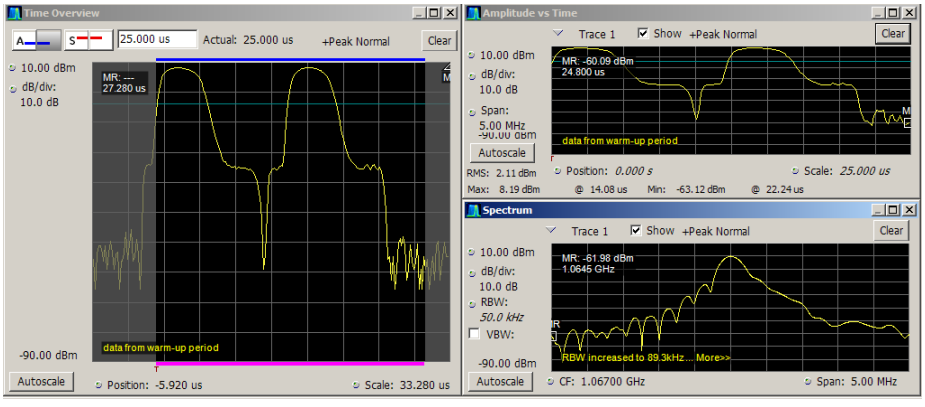

Fig. 1 measured pulse form DME-40 (Collins)

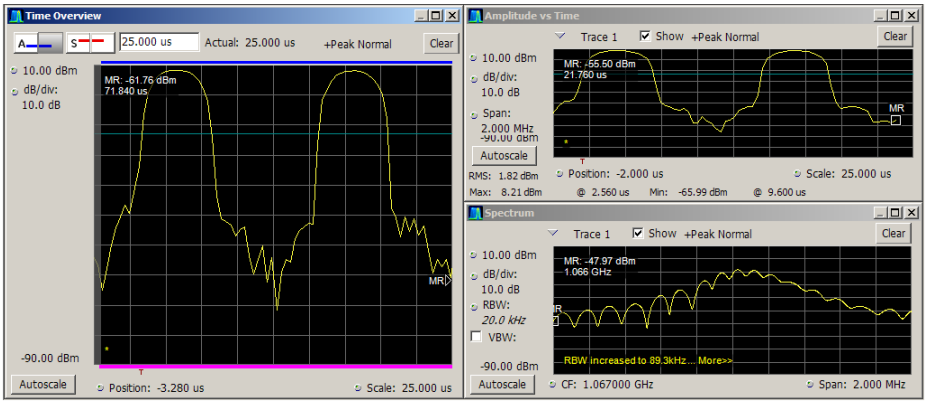

Fig. 2 measured pulse form KTU-709 (Bendix)

Increase of DME and TACAN pulse count and aggregate duty cycle in presence of multipath

Multipath is generated when strong signals generate longitudal- and or lateral-echos/-multipath (see figure below) generated by aircraft DME and TACAN interrogations. A more detailed description of DME and TACAN multipath can be found in FAA-6820.10.

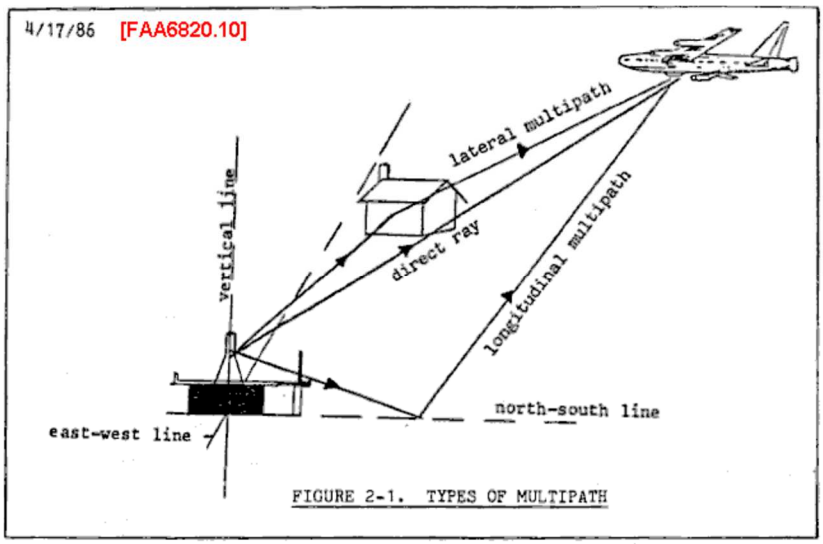

Fig. 3 longitudal- and or lateral-echos/-multipath[FSS-6820.10]

Short Distance Multipath

When echoes of pulses fall between interrogation pulse pairs or overlap them this considered to be short distance multipath.

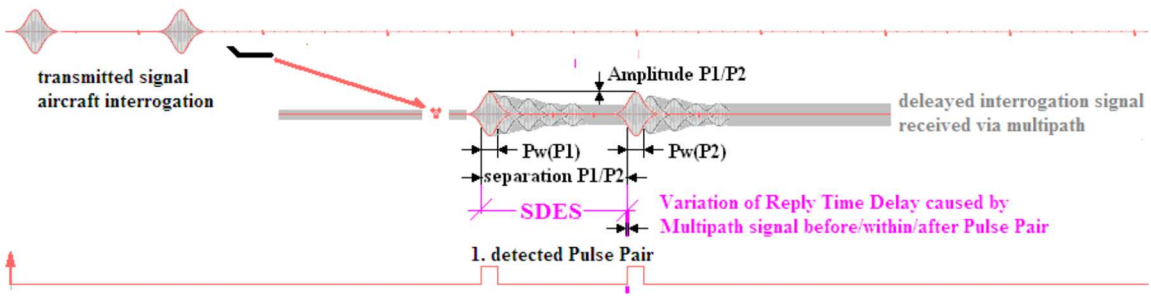

Fig. 4 short distance-echos/-multipath

To mitigate DME and TACAN transponder incorporate Short Distance Echo Suppression (SDES) circuits.

Long Distance Multipath

Echos arriving after the initial interrogation pulses are called Long Distance Multipath echos.

Multiple replies from the Frankfurt/Main TACAN were observed in 1969 during aflight inspection by BFS (Bundesanstalt für Flugsicherung). In addition to the transponder reply to the interrogation received via the direct path. a second and a third replies were generated by the transponder. The interrogation pulse pair were received via multiple reflections in the airport vicinity. Observation of the output signal of the logarithmic amplifier of the transponder identified a dense pulse train generated which was received as long as 150 µs after the initial interrogation pulse, before the amplitude of the multipath signals dropped below the set Minimum Triggering Level (MTL) of the TACAN receiver. US-FAA had identified similar occurrences. In consequence modifications to existing transponder, called echo traps, were made. Furthermore input material to ICAO lead to an amendment of ICAO Annex 10 with provisions countering multipath effects. Today DME and TACAN transponder have LDES and SDES circuits to counter multipath interference for up to 350 µs duation.

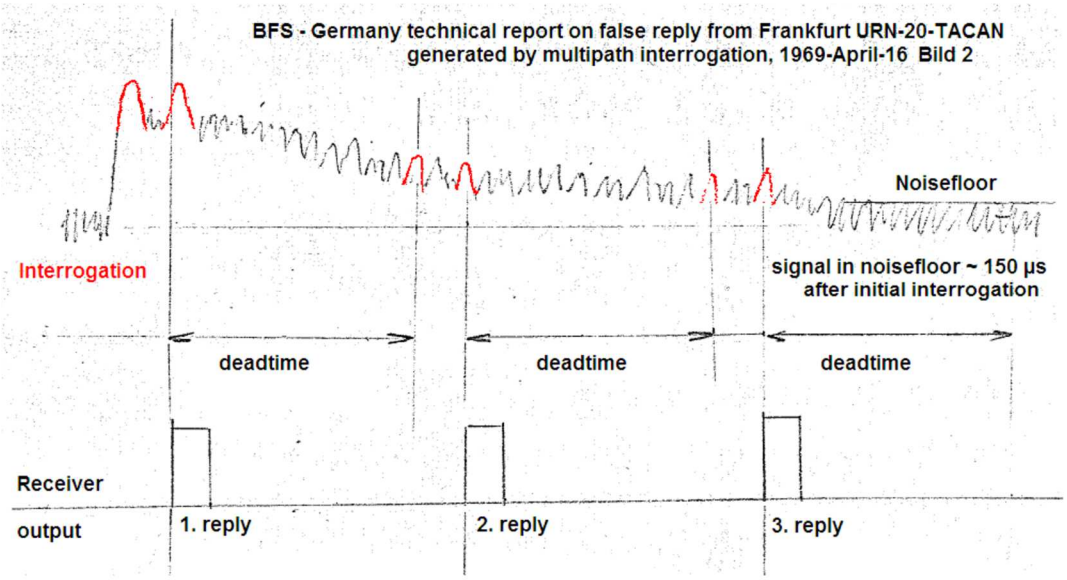

Fig. 5 long distance-echos/-multipath[BFS-RD-1969]

Conclusion

That strong aeronautical pulses, e.g. from DME and TACAN, can produce multipath echoes at most locations. Due to the large measured signal strength that can exceed -40 dBm [SE7(19)176] multipath echoes will be above receiver threshold and increase

- pulse width beyond the 3.5 µs ±0.5 µs specified for 50% amplitude points
- the number of pulses received and in extreme provide a continuous train of pulses with decaying strength for 150 µs or more.
- the aggregate duty cycle

Recommendation

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Reference documents:

[BFS-RD-1969] BFS-Germany Technical report on false reply from Frankfurt URN-20 TACAN generated by multipath interrogations

[FAA-6820.10] FAA-Order 6820.10 VOR, VOR/DME, AND VORTAC SITING CRITERI, APRIL 17, 1986

[ASP08-20] Effect of Multipath Echoes on Transponder Decoder, Shigeru Ozeki, ASP-WG8, WP ASP08-20, April 2010

[SE7(17)092], Compendium of systems and applications in the band 960 - 1125 MHz, Joachim Wollweber (DFS Germany), CEPT SE7 Wedemark 2017

[SE7(17)176], Measured vs. calculated peak aircraft signal strength between 960-1164 MHz at Langen (Germany) Joachim Wollweber (DFS Germany), CEPT SE7 Brussel 17-18.April. 2019