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Meeting #3

DME Circumvention and Signaling Alphabet allows DME to Coexist with UAT
&
Double Sideband Transmit/RAKE-like Receiver allow UAT to Coexist with L-16

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SUMMARY

This paper describes a system concept that allows a **new UAT waveform** to coexist with DME/TACAN and L-16 in the existing electromagnetic environment of the Radio Navigation Frequency band **without eliminating or reassigning DME channels**. The approach utilizes a continuous set of 16 DME Channels, organized into UAT Sub-Channels. **UAT's Transmit on locally vacant sub-channels (No DME/ TACAN) activity, but listen to all sub-channels.** This **T/R architecture** allows UAT's in neighboring geographical areas, that may transmit on a different locally vacant sub-channels, to be heard by UAT's in adjacent neighboring geographical areas. **UAT interference** on DME and DME interference on UAT is minimal and within the correctable error tolerance bounds of each system. **L-16 interference on UAT,** is handled by duplicating the above Sub-Channel Architecture (Double Side-band Transmit) on a set of frequencies greater than 15 MHz apart. The approach was described by the authors in a paper presented at the Melbourne WG-5 Meeting in February 01.

DME Circumvention and Signaling Alphabet allows DME to Coexist with UAT & Double Side-band Transmit/RAKE-like Receiver allows UAT to Coexist with L-16

Problem

At the meeting in Melbourne, BAE presented a Double Side-band Transmit/ RAKE-like Receiver architecture to solve the L-16 Multi-Net Interference problem on UAT. BAE's front-end circumvention approach showed superior performance over back-end FEC approaches, but did not address the practical problems of clearing additional DME frequencies for the extra Side-band.

The WG-5 Chairman summarized the consensus of the WG members…"The only way that a L-16 protection features like this would be considered is if it required fewer DME frequencies to be re-assigned, or worked in the background, such that no DME Channels would have to be re-assigned". It was further stated that if the later could be implemented, it would accelerate the UAT acceptance and approval process by at least five years. BAE took on the later challenge, which is the subject addressed in this paper.

System Solution Summary

This paper presents a concept that allows **UAT** to coexist with DME/TACAN and L-16 in the existing electromagnetic environment without eliminating or reassigning any DME channels. The approach utilizes a continuous set of 16 DME Channels organized into a UAT "Super Channel". In any given geographical area, Air and Ground UAT's transmit UAT Data on locally vacant DME/TACAN channels, but listen to the Super Channel for UAT Data Reception. As initially defined there is room for 16 independent receive channels in the defined Super Channel. BAE's is trying to drive the solution to 8 channels, each channel being 2 MHz wide. This would easily satisfy the 1 MHz data rate requirement of UAT.

The new UAT architecture described herein allows UAT's, with a surrounding continuous 150 nmi service volume, to transmit UAT messages on locally vacant DME/TACAN channels. Vacant channels are defined as channels, in a pre defined 16 MHz BW that have "no" DME activity on them, either because they were not assigned in that particular geographical area, or because a given Air vehicle is beyond the useful range (service volume) of a DME/TACAN ground station. In either case, a given air vehicle may choose this "apparent" vacant channel as its UAT transmit channel. The UAT transmission may affect some remote DME user on the subject channel, but at a signal to interference ratio (D/U ratio) that does not perceivably degrade the users DME/TACAN function. This is a complex subject that needs to be addressed in another WG-5 paper. For the purposes of this paper it is assumed that an acceptable D/U ratio can be found for all practical scenarios.

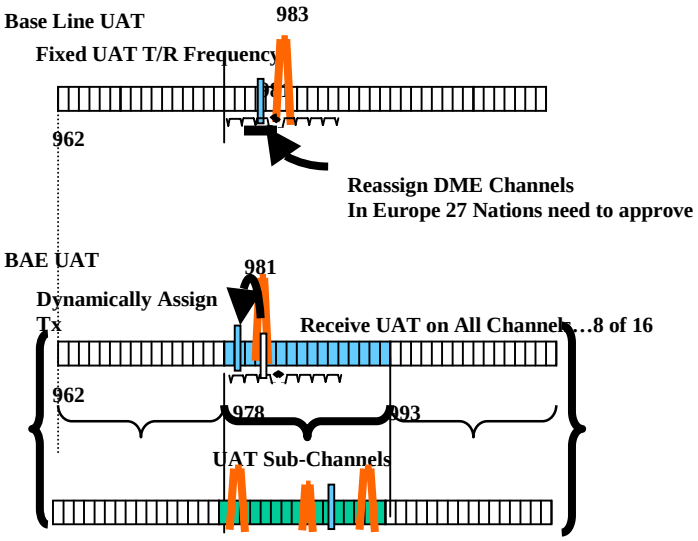
System Architecture Comparison

To implement the above "System Solution" BAE changed its modulation approach from a wide bandwidth Direct Sequence Spread modulation to M-ary FSK. This modulation

provided the desired features of a channelized signaling architecture that could be used to circumvent active DME stations in a local geographical area.

The differences in System Architecture, between the baseline UAT being specified today, and BAE's UAT proposal is highlighted in Figure 1, UAT System Architecture Comparison.

Figure 1-UAT System Architecture Comparison



From Figure 1, the following observations are apparent:

Baseline UAT System:

>Architecture requires 3 consecutive DME Channels to be re assigned.
>In Europe 127 nations need to agree and approve the reassignments.
>Could take 5+ years to get mutual agreement and ratification, if ever.
>Vulnerable to Multi-Net L-16 Interference…see Melbourne paper

BAE UAT

>No need to Shut-down / reassign DME frequencies for UAT
>Much easier approval process for adding "Background" UAT
>Could accelerate UAT acceptance and deployment by 5 years
>Double Sideband transmit provides robust solution to Multi-Net L-16

In the BAE proposal, the DME Circumvention process allows both DME and UAT to coexist in the same electromagnetic environment, without shutting down or reassigning DME Frequencies.

The above statements and the following material assumes it is possible to find locally vacant DME/TACAN frequencies, and when those frequencies are used by UAT, any interference to remote DME/TACAN users will arrive at reasonably low Desired to Un-desired (D/U) ratios. A major study, using actual DME/TACAN cite data (Lat/Lon, Freq,

Tx Power, etc) needs to be conducted for Europe and the USA. At the Brussels meeting BAE intends to request the required data from EUROCONTROL and the FAA.

From the UAT Receive function perspective, UAT is totaling forgiving. Individual UAT's that don't switch to a DME circumvention transmit frequency on time, or for that matter never switch to a circumvention frequency, will be received by all UAT's because they continually listen to all sub-channels. Every channel is an equally valid channel for reception. Channels that receive UAT Data on a local DME active channel will have a 3.2 % message error rate caused by On-Channel/ Adjacent-Channel DME interference which is easily corrected by the UAT's FEC function. Internal Built-in-Test functions will alert the Pilot that the equipment needs repair before the next flight.

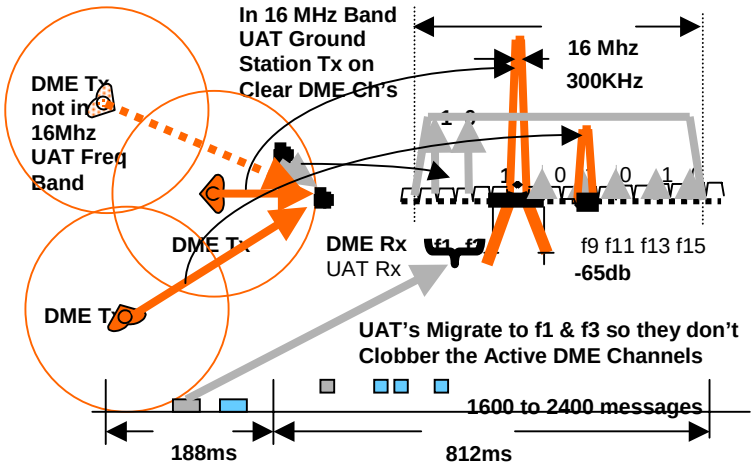
Getting UAT's to transmit on locally vacant DME Channels

There are several system level architectures that could be conceived to provide this function. The simplest way is for UAT to house a Regional (world-wide) data base. The Data-Base would be derived from survey data and would continually control the UAT Transmit function as a function of the Aircraft's Lat-Lon and possible Altitude. With a Data-Base on board, the system will always allow UAT to Circumvent active DME channels, even where there are no UAT Ground Stations in sight. Problematic issues associated with maintenance of air vehicle on-board Data Base's is an issue beyond the scope of this document.

If the BAE proposal is carried forward, more work on Frequency Management/on board Data Base Management would have to be pursued. This is in addition to validating that UAT interference to remote DME users will arrive at low D/U ratios as cited above.

Detailed Pictorial of System Concept

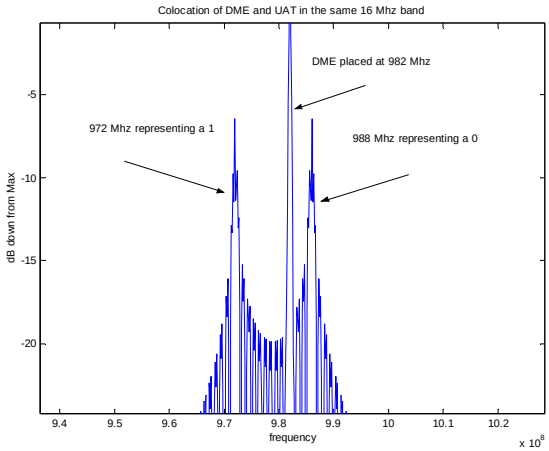
Figure 3 below operationally depicts BAE's proposal. Aircraft flying in and out of DME service volumes are commanded, by an on-board Data Base, to circumvent transmitting on locally active DME channels. The data Base for the local service volume or geographical area could be updated and/or confirmed each time a transceiver enters a UAT Service volume.



Even if a given UAT has a corrupted Transmit Assignment Data-Base, UAT Data will be exchanged. The UAT in question will produce minimal interference to the local DME/TACAN channel (once per sec) and the DME Channel will have an un-noticeable effect on the UAT in question. It's not until many Air Vehicles disobey their respective Transmit Channel assignment Data Base's, that both systems (DME/TACAN and UAT) become corrupted beyond operational limits.

Simulation of UAT Waveform in a DME environment

To substantiate BAE's claims of UAT being able to co-exist with DME, simulations were run using 2 MHz wide sub-channels and CPFSK Signaling. The figure below depicts a robust signaling format where logical 1's are represented by even channel frequencies starting at 972 MHz, repeating every 4 MHz in the 16 MHz Super-Channel BW, and logic 0's are transmitted starting at 974 MHz, repeating every 4 MHz in the 16 MHz Super-Channel.



As depicted and described there are 8 frequencies out of 16 that are used to convey UAT Data. The logical 1/0 signaling structure described above assumed that there would always be several locally vacant DME channels available. A more conservative approach is to assume a locally vacant channel to convey the entire UAT 1 Mbit/sec of data as being assumed in the baseline MITRE UAT approach. The final configuration defining the exact number of sub-channels required, their band-width, etc., will be defined after BAE assesses actual DME/TACAN site data. BAE intends to request this data at the Brussels meeting.

Smooth Transition from Current UAT to BAE's UAT proposal

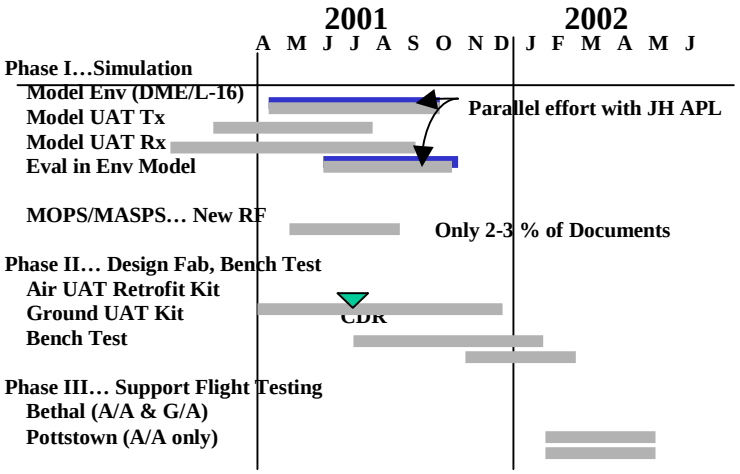
To aid WG-5 decision to carry the above approach to the next step, the following schedule is put forth which could be either executed in series with or in parallel with the two studies sighted in the text of this report and repeated here:

- Validate the concept of finding Locally Vacant Frequencies
- Determine need for Airborne Data Base and its maintenance

The validity of BAE's proposal hinges on the outcome of the above two studies.

BAE feels confident that the proposed circumvention approach to DME/TACAN channel re-use will be implementable... there will be locally vacant channels, over large service volumes all over the world. In a few congested areas in Europe and the US some innovative UAT Frequency Management techniques will be required, but for the majority of the air-space the frequency management will be simple.

Based on the above, BAE suggests that WG-5 authorize and fund a simulation and hardware activity to support this approach in parallel to the baseline approach. The following table depicts some of the tasks that need to get kicked off.



BAE is willing to lead this activity. The hardware approach is to design a form, fit UAT Transceiver that could be fitted into an existing UAT Box. The new Transceiver would interface with existing UAT RF, FEC, and DC Power interfaces. One Side-band would be tuned to what ever the existing UAT design settles to, and would be fully interoperable with existing UAT's, the other Side-band would be used to collect data on DME channel re-use for the US and European communities and for evaluating UAT robustness to Multi-Net L-16 interference.

WG-5 Actions
Consider funding this activity as a contingency approach for:

- Eliminating 127 Country (states) approval for re-assigning 3 consecutive DME/TACAN frequencies in Europe
- Meeting the **combined** effects of
  - Mutual Interference of UAT on UAT
  - DME Interference on UAT
  - L-16 Multi-Net Interference on UAT

The proposed architecture is fundamentally different than the baseline. It attacks the interference problems in the RF processing area, rather than in the digital FEC area. With the proposed approach only a small amount of FEC is needed and thus the Payload Message thru-put can be increased back to what was advertised a year ago.