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UAT MOPS

Meeting #2

Two-Frequency UAT Evaluation

Authors: T. Mosher, UPS AT
R. Kulpinski, MITRE

SUMMARY
Presents results of evaluation into feasibility of defining a 2-Frequency UAT requirement.

Introduction

At the first meeting of SC-186 WG5 (UAT MOPS), representatives of the FAA requested an evaluation of the feasibility of defining a UAT that can operate on either one of two pre-defined frequencies. This paper presents the results of this evaluation.

Certain guidelines were given by the working group, or were assumed by the authors, in the development of this paper, as follows:

1. The two frequencies are selected so that one is above 977 MHz, and the second is below 977. The authors selected 966 MHz and 981 MHz as the basis for the evaluation. Other specific frequencies could be selected without greatly altering the conclusions of this evaluation.

2. Performance of the radio is to meet or exceed that of the current UAT implementation, as used in the SF21 and Capstone programs.

3. Operation on one of the two frequencies at a time is sufficient. The frequency of operation may be selected by use of external program pins, or any other method such that no dedicated cockpit control panel is required. Switching between the two frequencies is not necessary while in normal operation. Frequency selection via program pins is likely a minor increase in cost of aircraft provisions. Frequency selection through a dedicated cockpit control panel could add significant cost to aircraft provisions.

4. Factors in the evaluation include hardware costs, certification costs, manufacturing costs and effect on voluntary equipage.

5. Cost factors are given in terms of normalized increased costs over a single-frequency design, with performance equivalent to the existing SF21/Capstone UAT equipment.

Disclaimer

Readers are cautioned that this evaluation is a feasibility study only. A specific design was selected for evaluation, for purposes of estimating feasibility factors. Other design architectures are entirely possible, and the design discussed in this paper is not to be interpreted as a MOPS requirement.

Hardware Aspects - Receiver

The following block diagram represents the radio receiver architecture selected for evaluation. Note that this represents only one possible design, but evaluations based on this design should apply equally to other architectures. This design optimizes for the highest image rejection and spurious free dynamic range.

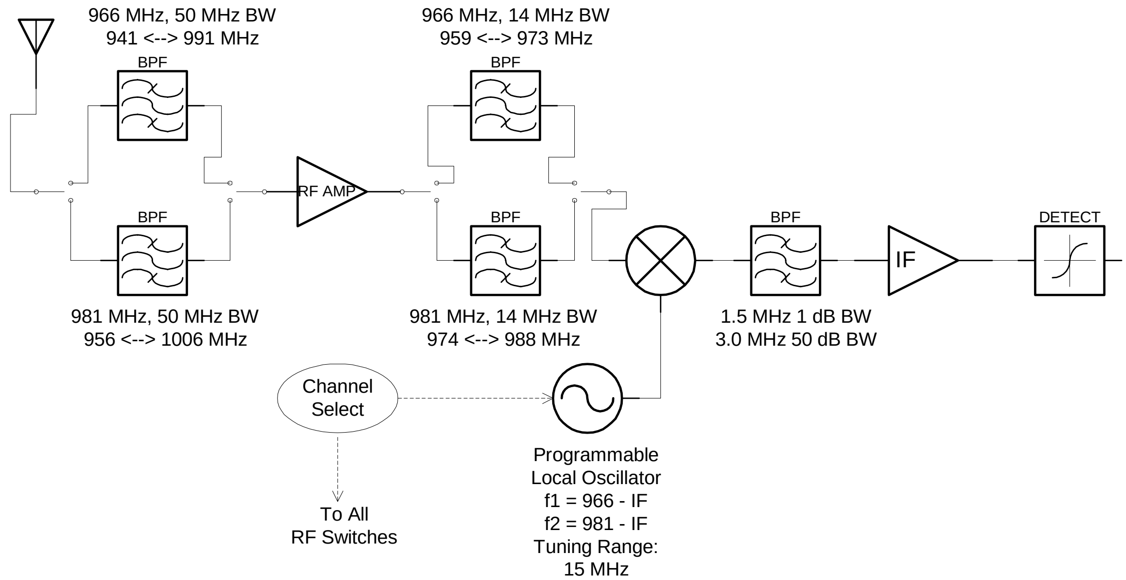

Figure 1 Receiver Architecture

Discussion of architecture:

The basic architecture is a single-conversion fixed-IF frequency FM receiver. The front end filtering is accomplished by a pair of passive bandpass filters, separated by an RF amplifier. The filter characteristics are selected to best match the compromises of low insertion loss, small size, low cost, low total noise figure, and sufficient protection of the mixer stage against strong out-of-band interferers. The pairing of a wide filter, followed by an RF amplifier and a narrower filter, has shown to be an effective combination. The wide filter has a bandwidth of 50 MHz, and the narrow filter has a bandwidth of 14 MHz.

In order to accomplish the dual-frequency capability, the diagram shows two separate banks of filters, being switched in unison between the top and bottom pairs, depending on the channel selection. The additional costs associated with this design include the need for a second bank of filters, and the RF switches that control them.

Local Oscillator:

Tuning the radio consists of switching the Local Oscillator between two discrete frequencies. Using low-side injection results in an image frequency in the mid-800 MHz region, assuming the selected IF frequency is near 70 MHz. The LO must be tunable over a range of 15 MHz. Methods exist which will allow tuning over this range without raising the noise bandwidth excessively. However, the added range represents an increased cost over a single frequency design.

IF Filtering and Demodulation:
The IF Filter/Amp and Demodulation stages are unaffected by the channel selection. Note that the IF filter bandwidth used in the current UAT hardware is unnecessarily wide, as discussed in the receiver performance improvement working paper. Optimization of the IF bandwidth is a separate issue from the 2-channel concept.

Physical size:
The physical size increase for the 2-channel UAT is approximately 25% of the radio portion of the equipment.

Hardware Aspects - Transmitter

The following block diagram represents the transmitter architecture selected for evaluation. This concept explores the possibility of using a single wideband passive filter, so that filter switching is not required. Minimization of insertion loss is not a requirement for the post-mixer filter, since its task is primarily suppression of transmitter images. This allows for a more economical filter specification.

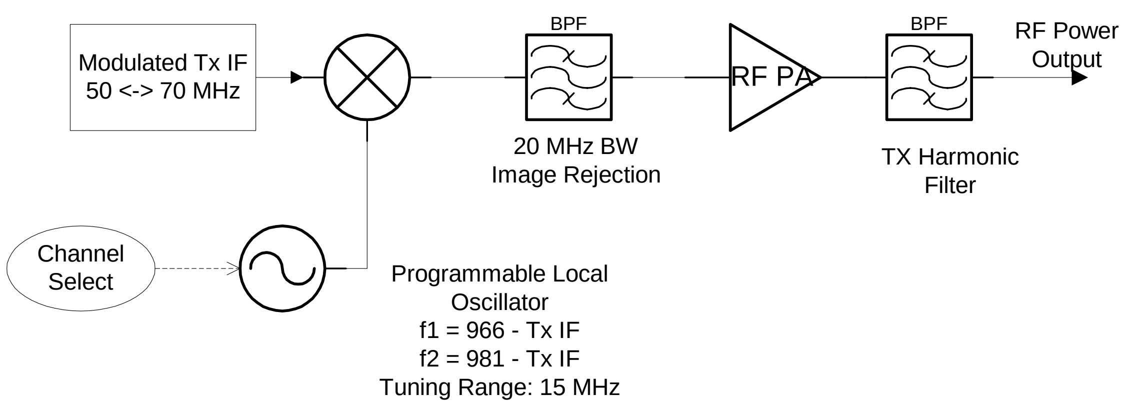

Figure 2 Transmitter Architecture

The transmitter local oscillator must switch between the two channels separated by 15 MHz. The most economical design would share a single LO between the receiver and transmitter. Since the FM modulation does not require a linear amplifier, a single RF Output Power Amplifier can be used without fine tuning for the output frequency. Harmonic suppression filtering will not be affected by the comparatively narrow shift in operating frequency between the two channels.

Note that the Transmit and Receive LO frequencies are selected at the discretion of the designer. There is no requirement for the receiver and transmitter to share a common LO.

If one does assume that the LO is shared, there is no additional cost penalty for a tunable transmitter LO for the 2-channel requirement. Additional costs are only associated with the image rejection filter. A 20 MHz-wide filter that achieves sufficient image rejection for both channels will be more expensive and larger than a single frequency filter.

A single-frequency filter could well have the same filter characteristic as the narrow receiver bandpass filters. This allows a further cost advantage for the single-frequency case, due to greater economy of scale from purchasing a larger quantity of the same filter design.

<u>Physical Size:</u>
Because no filter bank switching is performed, the 2-channel requirement has a negligible effect on the size of the transmitter portion of the UAT. Note that if the designer elects to switch the transmitter image filter (similar to the receiver design), a similar size penalty will be incurred (25%).

Certification Aspects

Many of the requirements for DO-160 environmental tests must be performed with the equipment exercised in its normal operating condition. If two operating frequencies are designated, many of the environmental tests will need to be repeated for each channel. Tests that will need to be performed for each channel include the following:

- RF Emissions
- Conducted and Induced AF Susceptibility
- RF Susceptibility
- Temperature, Altitude, and Temperature Variation
- Operational Shock and Vibration
- Humidity (Equipment only tested at completion of humidity exposure period)
- Power Input

In some cases, tests for the two channels can be performed in parallel (i.e. set up a test condition, perform tests on Channel A, perform tests on Channel B, proceed to the next test condition). Even with this accommodation, substantially more time will be required to perform, analyze, prepare, and review the environmental test reports, than for a single-frequency UAT.

Tests to obtain an FCC Grant of Authorization and ID number will also need to be performed for each channel, resulting in greater costs.

Certification costs for obtaining an STC for each airframe type will also increase, since many of the tests (EMC compliance, etc.) will need to be performed for both channels.

These costs are one-time expenses, which are amortized over the production life cycle. Multiple product life-cycles are expected to occur before full equipage is reached.

Manufacturing Aspects

Standard test equipment for the UAT will not be commercially available for some time. Therefore most UAT production test equipment will likely be constructed by the manufacturer. For a two-channel Test Set, the equipment will be more complex, and test procedures will take longer to develop. These represent additional one-time expenses, which are amortized over the production life cycle. The costs for production testing and quality assurance are all higher for the two-channel UAT. These increased costs are incurred for each unit manufactured.

Marketing Aspects

Adding complexity to the equipment can increase both the total costs of product development and the physical size, both of which have an effect on the marketability of the product.

On the negative side, a more complex UAT will be more expensive to produce, and will be physically larger by proportionally the same amount. This could reduce the size of the total market, and perhaps preclude applications where small physical size is a primary requirement (i.e. panel mount products).

On the positive side, the administrative flexibility that the two-channel UAT provides may lead to earlier and more universal adoption, which would serve to increase the total market. A potential drawback is that the lack of a single defined frequency may instead delay international adoption, due to uncertainty over the ultimate frequency selection.

The two portions of the avionics market (GA and Air Transport) are subject to very different forces. For example, in the GA fleet voluntary equipage is highly sensitive to cost. Market analysis shows that a 40% increase in the cost of the UAT Datalink would cause a 35% to 50% decrease in voluntary GA equipage.

Complete resolution of these positive and negative market factors is beyond the scope of this paper.

Other factors beyond the scope of this investigation

One central concept to this evaluation is that the UAT channel selection need not be altered in mid-flight. (see assumption #3 on page 2). Whether this meets the operational needs of a practical application is open to debate. One likely scenario is an aircraft flying between two national airspace regions that do not share the same UAT frequency assignment.

We have identified alternatives that can address this issue. Both alternatives involve modifications to other aircraft systems in a potentially expensive manner.

- A “UAT Channel” switch could be installed in the cockpit. Channel selection would be under pilot control. This raises many certification issues regarding crew workload and safety of flight.

- Automatic channel selection performed within the UAT itself, based on ownship geographic position. This raises issues about geographic frequency database maintenance and field updates, since the frequency space is unlikely to remain static over time.

Resolution of this issue is beyond the scope of this paper.

Conclusion

The following table summarizes the likely costs associated with a two-frequency requirement. The baseline costs for a single frequency UAT are arbitrarily normalized to 1.0 units for each cost category. The baseline costs depend on the technology that is selected and are expected to change over time.

- Non-recurring charges such as certification and fixed manufacturing cost are amortized over typical production volumes for a given design life-cycle.
- Periodic re-engineering and re-certification is expected, due to the length of time required to achieve "full" equipage, as well as new requirements from future MOPS revisions.

There will be no single UAT product. Multiple UAT products will exist, each suited for a particular market niche and service category. This fragmentation of the market results in proportionally higher per-unit costs to amortize the expenses of product development and certification.

Factor	**Single Frequency**	**Dual Frequency**
Hardware/Design Cost	1.0	1.25
Certification Cost	1.0	1.50
Manufacturing Cost	1.0	1.50
Total Cost (applying 50/10/40 typical weight factors)	1.0	1.40

- After applying weight values to each of the cost factors, and accounting for typical production volumes and life cycles, the total cost increase for the two-frequency UAT is approximately 40%.

The balance between cost, features, and market is not an exact science. The conclusion reached by this study is perhaps more qualitative than quantitative, but the conclusion should be representative over a wide range of these variables. Recognition of the range of factors contributing to total product cost should prove valuable to the UAT MOPS committee in deciding this issue.