FCC TYPE CERTIFICATION REPORT
FOR THE
SCAT-I VHF DATA LINK

October 7, 1999

Table of Contents

1 OVERVIEW

The VHF SCAT-I data link is a D8PSK transmitter intended to communicate with aircraft within a 20 Nmi area surrounding an airport. It is a sub-component of the overall DIAS-3100 ground station. It is not intended to be sold as an independant commercial data link. The paragraphs that follow provide the in-depth technical information concerning this data link.

2 INSTALLATION AND OPERATORS MANUAL

Because this data link is not a separate product, there is no unique operators manual for it. The installation and operators manual is for the entire DIAS-3100 system (attachment Master.wpd). This paragraph will provide the section and page number of pertinent information concerning the data link. The manual was included as an attachment.

Section 2-2.2.4 pages 2-6 through 2-8
Section 2-4.3 page 2-17
Section 2-4.6 page 2-19
Section 2-4.9.1 page 2-19
Section 2-5.2 page 2-25
Section 2-6.12 page 2-29 through 2-33
Section 3-4.4.1.3.1.2 pages 3-31 through 3-32
Section 4-2.1 page 4-3
Section 4-2.3.3 page 4-5
Section 5-2.3 page 5-9 through 5-10 (VHF Ref Shutdown Xmit Comm Link, Data Link Interference, and TDMA Slot Power Fail)
Section 5-5.1.3 page 5-24
Section 5-5.2.7 page 5-26
Section 5-6.6 page 5-29 and 5-30
Section 5-6.7 page 5-30 through 5-32
Section 5-6.8 page 5-32
Section 5-7 page 5-38
Table 6-1 page 6-3 through 6-4

3 TYPE OF EMISSION

The transmitter produces a differential 8-state phase-shift keyed (D8PSK) signal with an emission designator 14K0G7D. The class of emission is G7D.

4 FREQUENCY RANGE

The transmitter operates in the frequency range 112.0 MHz to 117.95 MHz. The frequency of operation is commanded via the transmitter control bus. The operating frequency channels are separated by 25 kHz.

5 POWER

The transmitter operates at a maximum power level of +40.0 dBm (minimum) adjustable in 32 steps of 0.5 dB each down to approximately +25 dBm. The power setting is commanded via the transmitter control bus.

6 MAXIMUM POWER RATING

Power and antenna height are restricted to the minimum necessary to achieve the required service. No specific maximum power rating is imposed.

7 PA SUPPLY POWER

The final amplifier is a single FET that is operated with nominal drain voltage of +28 Volts. Nominal FET current draw is approximately 2.5 Amperes.

8 TUNE-UP PROCEDURE

The transmitter RF circuitry is broad-banded over the entire operating frequency range. No transmitter tune-up procedure is performed by the end user.

9 CONTROL OF TRANSMITTER EMISSIONS

9.1 Frequency Control

The 20 MHz crystal-controlled clock oscillator U3 (attachment 197Sheet3) provides the time base for generation of the 25 kHz center frequency of the baseband-modulated signal produced by the digital signal processing circuit card. This signal then flows to the transmitter upconverter circuit card.

As seen on sheet 1 of schematic diagram E200195 (attachment E200195a), the 25 kHz baseband-modulated signal flows from the upconverter circuit card input connector through amplifiers U1 and U3 into mixer U4. U6 is a 10 MHz OCXO (oven-controlled crystal oscillator) that provides the fundamental time base for converting the transmitter baseband signal to the RF transmitting frequency. The first step in this conversion is accomplished by mixer U4, which combines the 25 kHz baseband-modulated signal with the 70 MHz 1st LO, mixing the baseband signal up to the 70.025 MHz IF frequency. U7 buffers the 10 MHz OCXO output signal, then filter FL1 selects the 7th harmonic (70 MHz) and routes it through amplifiers U10 and U11 to the LO port of mixer U4.

Schematic diagram E200195 sheet 2 shows IF crystal filter FL2, which has a 70.025 MHz center frequency and a 16 kHz bandwidth to select only the desired mixing product. U12 amplifies the

IF signal and routes it to mixer U13 for conversion to the transmitter output frequency.

The synthesizer, which produces the second LO signal, consists primarily of synthesizer control U22, VCO U16, and dual-modulus pre-scaler U20. U22 controls the modulus of the pre-scaler and also contains the phase-locked loop digital phase comparator, the output of which flows to the active filter to remove reference frequency signal components and other undesired noise. U21 is part of the synthesizer active loop filter that provides the control signal to the VCO. The output signal from the VCO flows through amplifiers U17, U2, and U18 to the LO port of mixer U13. U19 amplifies sampled VCO power and buffers the input port of the pre-scaler. This phase-locked loop synthesizer produces an LO signal frequency in the range from 182.025 MHz to 187.975 MHz. The LO frequency mixes with the 70.025 MHz IF in mixer U13 to produce output signals in the range from 112 MHz to 117.95 MHz, the final transmitter output frequency range. U22 accepts clocked tuning data from the digital controller card to divide the OCXO-derived 10 MHz reference frequency and to control the dual modulus pre-scaler for the desired synthesizer output frequency.

9.2 Suppression of Spurious Signals

IF filter FL2 on schematic diagram E200195 sheet 2 (attachment E200195a) has 16 kHz bandwidth with very steep skirts to suppress undesired mixer products and all other noise generated prior to this point in the signal path. Filter FL3, which covers the transmitter output frequency band 112 MHz to 117.95 MHz, removes undesired mixer products that may have been generated in mixer U13. Power amplifier filter FL1 ,shown on E200196 sheet 1, (attachment E200196_) suppresses harmonic power at multiples of the transmitter output frequency.

9.3 Limiting Modulation

The D8PSK signal is generated by established methods according to FAA requirements using the transmitter's digital signal processing circuit card assembly. The symbol rate of 10500 symbols per second, which is equivalent to a modulation rate of 31,500 bits per second, is controlled with the timebase established by the 42.0 MHz crystal oscillator U4 shown on schematic diagram E200197 sheet 5 (attachment 197Sheet5).

9.4 Power Limiting

Schematic diagram E200196 sheet 1 shows directional coupler U2, which samples the transmitter RF output port forward and reverse power. CR1 detects the sampled forward power, producing a video signal that is amplified by U6 (seen on sheet 2 of the schematic diagram). U7 compares the amplified video voltage, representing the RF output power, with a reference voltage that represents the maximum allowable output power, approximately +44 dBm. In case of transmitter malfunction resulting in excessive transmitter RF output power, comparator U7 triggers a latch on U5 that disables the transmitter until an externally-generated reset command is sent to clear the latch.

10 EQUIPMENT IDENTIFICATION

The photographs of the equipment identification plate and the actual equipment are included as attachments. There are 11 photos total. The filenames indicate what aspect of the transmitter is included in the file. The power amplifier photo corresponds to the E200196_ drawing. The pre-amplier (upconverter) photos correspond to the E200195a drawing. The digital board photos correspond to the 197SheetX drawings. Included also are a system box level photograph, a front panel closeup view, a rear panel close up view, and a side view photo of the boards in the box with the internal shielding. All photograph names begin with Pic.

11 DIGITAL MODULATING TECHNIQUE

The modulation scheme used for this data link transmitter is differential eight phase shift key (D8PSK). The D8PSK type of modulation differentially phase shifts the carrier with respect to the previous phase using eight different phase shift possibilities. These phase shifts are dependent on the code. The eight possible phase shifts are evenly spaced and include the phase possibilities of 0, 45, -45, 90, -90, 135 , -135 and 180. Each shift provides three bits of information. Since this is a differential system, these phase shifts are referenced to the previous bit, not the absolute phase. The symbol rate is 10.5 ksps and therefore the bit rate is 31.5 Kbps and a bandwidth of 21 KHz.

The binary data stream entering a differential data encoder is converted into three separate binary streams X, Y and Z so that bits 3n form X, 3n+1 form Y and bits 3n+2 form Z. The triplet at time k (X_k, Y_k, Z_k) is converted to a change in phase as shown in the table below and the absolute phase $\_{k}$ is the accumulated series of $\_\_{k}$.

$$\_{k} = \_{k-1} + \_\_{k}$$

<u>Data Encoding</u>

X_k	Y_k	Z_k	$\Delta\phi_k$
0	0	0	$0\ \pi / 4$
0	0	1	$1\ \pi / 4$
0	1	1	$2\ \pi / 4$
0	1	0	$3\ \pi / 4$
1	1	0	$4\ \pi / 4$
1	1	1	$5\ \pi / 4$
1	0	1	$6\ \pi / 4$
1	0	0	$7\ \pi / 4$

The transmitted signal is $H(e^{j(2\Pi ft+\_(t))})$, where H(˙) Is a raised cosine filter with $\propto = 0.6$.

By shaping the pulse rather than hard filtering, the bandwidth is reduced as well as the Inter Symbol Interference (ISI).

The frequency and time response of the baseband filters are defined as:

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where f is the absolute value of the frequency offset from the channel center, T is the symbol period of 1/10500 sec (or approximately 95.2 μsec), and α is 0.6.

The input data stream is FEC encoded, bit scrambled, and fed to a serial to parallel converter to allow for selection of the delta phase based on three consecutive bits. This delta phase is added to the previous absolute phase to produce the D8PSK waveform. This signal is quadrature upconverted to the 25 KHz IF using a 25 KHz I/Q digital oscillator and output to the D/A converter. The hardware processing was defined earlier in this report.

12 MEASUREMENTS

12.1 47 CFR 2.1046 Measurements required: RF power output

This requirement is satisfied by submission of qualification test results in 4.18, Nominal Output Power.

12.2 47 CFR 2.1047 Measurements required: Modulation characteristics

This requirement is satisfied by submission of qualification test results in 4.16, Quadrature Modulation.

12.3 47 CFR 2.1049 Measurements required: Occupied bandwidth

The transmitter authorized bandwidth for class G7D is 25 kHz, as shown in the newly-revised

47CFR 87.137 Types of Emission, reported in Report and Order FCC 99-40. 47CFR 2.1049 requires that the total power above and the total power below the specified occupied bandwidth limits are each less than 0.5 % (-23 dB) of the total output power. Figure 1 (attachment Figure1), which is a plot of the spectrum of the transmitter output signal, shows that the power at the occupied bandwidth limits (+/- 12.5 kHz) drops off to approximately 45 dB below the mid-channel power level. The plot also shows that the 3 dB bandwidth is approximately 10 kHz. Attachment Figure2, which is a plot of the transmitter output signal spectrum over a 5 MHz span, shows that the transmitter power is concentrated at the 112 MHz assigned output frequency, without prominent spectral components adding significant power above or below the specified occupied bandwidth limits. Based on the foregoing inspection and analysis we conclude that the transmitter meets the occupied bandwidth requirement.

12.4 47 CFR 2.1051 Measurements required: Spurious emissions at antenna terminals

The spurious emission power limits close to the transmitter output frequency are the tiered limits cited in newly-revised 47CFR 87.139, Emission limitations subparagraph (j), reported in Report and Order FCC 99-40. These limits extend down to -52 dBm at +/- 2.1 MHz, the frequency offset corresponding to the upper and lower 84th adjacent channels. Beyond that frequency, the output power must be suppressed relative to pY by 43 + 10 $\log_{10}$ pY dB, as defined by subparagraph (d) for ground stations. pY is the on-channel RF output power.

Our transmitter operates in a cabinet with cables, connectors, and an RF switch between the transmitter module RF output port and the cabinet RF output connector, accounting for approximately 2 dB of loss between the transmitter and the system cabinet RF output port. There is additional cable loss between the cabinet and the antenna. Because the transmitter is always deployed in such a configuration, the limits mentioned in the previous paragraph must be raised by 2 dB for testing the transmitter alone, which effectively references the original limits to the system cabinet output connector.

A copy of qualification test results 4.21 (Adjacent Channel Emissions) is included to demonstrate spurious emissions compliance at relatively close-in frequencies. Employing the 2 dB loss factor mentioned in the previous paragraph, the extensive test results provide evidence of requirement compliance over the frequency range from +/- 50 kHz (second adjacent channels) to +/- 1.6 MHz (64th adjacent channels). Attachment Table1 is additional data showing that power levels in the 84th adjacent channels (+/- 2.1 MHz), which are below -50 dBm, also comply with the requirement.

The transmitter module RF output power (before the previously-mentioned 2 dB system cable attenuation) is less than or equal to +12 dBW (+42 dBm). Using the remote-frequency attenuation calculation, less 2 dB to account for system losses, the ultimate attenuation beyond +/- 2.1 MHz for the transmitter module is 53 dB below the on-channel output power (43 + 12 - 2 = 53 dB). This puts the power limit for harmonics and other spurious power in this frequency range at -11 dBm (+42 dBm - 53 dB = -11 dBm).

Attachment Figure3 shows the transmitter output signal spectrum from 10 MHz to 1.0 GHz, with the ultimate power level limit line shown at -11 dBm. Attachment Figure4 shows the extended spectrum from 1.0 to 2.0 GHz with the same limit line. These figures show compliance with the spurious emissions requirement, with only three prominent spectral components approximately 10 dB to 20 dB below the limit line. The two most remote components are harmonics of the main signal, appearing at 224 MHz and at 336 MHz. The third is a low-level internally-generated spurious signal appearing approximately 14 MHz above the selected transmitting frequency.

12.5 47 CFR 2.1053 Measurements required: Field strength of spurious radiation

Raytheon engaged the services of DNB Engineering, which has FCC-certified EMC testing facilities, to analyze spurious radiated field strengths. Their data (attachment Figure5) with explanatory notes (Notes C.1) are attached for field strength measurements collected on their 3-meter range. Their calculations show that spurious radiation must be suppressed at least 53.79 dB relative to the desired on-channel data transmission power. The right-hand data table column shows that worst-case suppression occurred with horizontal polarization at the 5^{th} harmonic of the channel center frequency with spurious radiation suppressed by 84.93 dB. All other spurious radiation was suppressed even more. As shown by the test report, the UUT meets the spurious radiation field strength requirement of 47 CFR Part 2.1053 "Measurements required: Field strength of spurious radiation."

12.6 47 CFR 2.1055 Measurements required: Frequency stability

This requirement is satisfied by submission of frequency stability data (attachment Table 2) over temperature and voltage collected on 13 July 1999.

12.7 47 CFR 2.1057 Frequency spectrum to be investigated

In all of the measurements set forth in Secs. 2.1051 and 2.1053, the spectrum was investigated as required by the provisions of the referenced section.