ANSI/TIA-102.CAAA-E-2016
APPROVED: MARCH 2, 2016

# TIA STANDARD

## Project 25

# Digital C4FM/CQPSK Transceiver Measurement Methods

TIA-102.CAAA-E
(Revision of TIA-102.CAAA-D)

March 2016

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## Foreword

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This document has been submitted to APCO/NASTD/FED by the Telecommunications Industry Association (TIA), as provided for in a Memorandum of Understanding (MOU) dated April 15, 1992.

This standard was developed and will be maintained by the TR-8.1 Subcommittee on Transceiver Measurement Methods under the sponsorship of the Telecommunications Industry Association. This standard represents the consensus of the formulating subcommittee at the time of publication. This standard replaces TIA-102.CAAA-D, which was originally published in April 2013.

This document describes the methods of measurement for digital land mobile radio equipment designed for compliance with relevant TIA-102 specifications. These methods are necessary to provide a basis for ascertaining performance of equipment of various manufacturers. This document includes a normative annex that gives software for performing trunking operational testing.



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# 1. INTRODUCTION

## 1.1 Scope

This standard provides definition, methods of measurement, and performance standards for radio equipment used in the Private (Dispatch) Land Mobile Services that employ C4FM or CQPSK modulation, for transmission and reception of voice or data using digital techniques, with or without encryption, with a frequency of 1 GHz or less. Document **[R1]** defines the requirements of both the Physical Layer and the Data Link Layer in the OSI reference model for the radio interface in which this equipment operates.

Use of this standard is encouraged for any application of similar equipment with C4FM or CQPSK modulation. However, this standard is not intended to cover transceiver equipment employing any or all modulation types or access methods. Therefore, the applicability of this document to digital transceiver equipment other than that called out in the scope must be carefully examined.

## 1.2 Object

The object of this standard is to standardize parameter titles, definitions, the test conditions, and the methods of measurement used to ascertain the performance of equipment within the scope of this standard, and to make possible a meaningful comparison of the results of measurements made by different observers and on different equipment.

## 1.3 References

### 1.3.1 Normative References

The following documents contain provisions that, through reference in this text, constitute provisions of this document. At the time of publication, the editions of the indicated were valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. The American National Standards Institute (ANSI), TIA, and other organizations maintain registers of currently valid standards published by them. The appearance of Project 25 in document titles referenced herein indicates the document has been adopted by APCO/NASTD/FED Project 25 Steering Committee as part of its Project 25 standard.

**[R1]** ANSI/TIA-102.BAAA-A; Project 25 FDMA – Common Air Interface; September 2003



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**[R2]** ANSI/TIA-102.CAAB-D; Land Mobile Radio Transceiver Performance Recommendations, Project 25 Digital Radio Technology, C4FM/CQPSK Modulation

### 1.3.2 Informative References

**[R3]** TIA TSB-102-B; Project 25, TIA-102 Document Suite Overview; June 2012

## 1.4 Standard Definitions

### 1.4.1 Definitions of Physical Values

Standard definitions of terms can be found in document **[R3]**, and in IEEE Standard Dictionary of Electrical and Electronics Terms.

### 1.4.2 Common Definitions

This section details common definitions for the characteristics and measurements of C4FM or CQPSK digital private land mobile equipment in vehicular (mobile), fixed (base station), or handheld (portable) installations.

#### 1.4.2.1 Standard Continuous Duty Cycle for Mobile and Base Equipment

Transmitter continuous operation denotes operation of the transmitter at rated power output into the manufacturer's specified load continuously for 24 hours.

Receiver continuous operation denotes operation of the receiver at rated audio frequency output power into the manufacturer's specified load continuously for 24 hours.

#### 1.4.2.2 Standard Intermittent Duty Cycle for Mobile and Base Equipment

The standard duty cycle for intermittent operation is 4 minutes receive at rated audio output power followed by 1 minute transmit at rated transmitter output power, both under the manufacturer's specified load, for a period of 8 hours, followed immediately by three cycles of 15 minutes receive and 5 minutes transmit, both at rated power.

#### 1.4.2.3 Standard Duty Cycle for Portable Equipment

The standard duty cycle, measured under manufacturer's specified load, for portable equipment may be one of the following:



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a) 10-10-80: 6 seconds transmit at rated power output, 6 seconds receive at rated audio output power, and 48 seconds standby;

b) 5-5-90: 3 seconds transmit at rated power output, 3 seconds receive at rated audio output power, and 54 seconds standby; or

c) 5-45-50: 3 seconds transmit at rated power output, 27 seconds receive at rated audio output power, and 30 seconds standby.

If the equipment does not contain either a transmitter or a receiver, the corresponding part of the duty cycle shall be replaced by the equivalent additional seconds of standby. The standard duty cycle shall be performed over the hours specified by the manufacturer for equipment with a battery life of less than 16 hours, and for 8 hours followed by a 16 hour rest for equipment with a battery life of over 16 hours. The 8 hour test and 16 hour rest cycle is continued until the specified life of the battery is reached.

### 1.4.3 Definitions for Receivers

This section details definitions for the characteristics and measurements of digital private land mobile receivers in vehicular (mobile), fixed (base station), or handheld (portable) installations.

#### 1.4.3.1 Input Signal Level for Testing Receivers With Suitable Antenna Terminals

The nominal radio frequency impedance ($R_n$) is that value stated by the manufacturer at the port for which the equipment performance will be measured.

The input signal level for receivers will be expressed as a power, in dBm, delivered to an impedance having a value of $R_n$. This level may also be expressed in μV across $R_n$, with the value of $R_n$ noted. For nonconstant envelope modulation, the signal level shall be the rms value of the signal.

NOTE: When the signal source is not in close proximity to the receiver input terminals, the transmission line loss must be taken into account, in addition to the loss of any impedance matching networks.

#### 1.4.3.2 Standard Input Signal

Standard input signal is defined as a radio frequency signal at standard input signal level, with standard input signal frequency, at the standard modulation of the input signal.



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#### 1.4.3.3 Standard Input Signal Level

Standard input signal level is -47 dBm (1000 μV into 50 Ω).

#### 1.4.3.4 Standard Input Signal Frequency

Standard input signal frequency for all tests is the nominal specified receiver frequency.

#### 1.4.3.5 Standard Modulation of an Input Signal

Standard modulation of an input signal is modulation resulting from one of the digital four level standard symbol patterns applied to the modulator at a rate of 4800 symbols per second. The modulation shall be the manufacturer's choice of one of the following, as per **[R1]**, except where specifically stated in the methods of measurement detailed in this document:

a) C4FM

b) CQPSK

#### 1.4.3.6 Standard Simulcast Modulation of an Input Signal

Standard simulcast modulation of an input signal is modulation resulting from one of the digital four level standard symbol patterns applied to the modulator at a rate of 4800 symbols per second. Simulcast modulation is intended for use by the fixed station transmitter. The Standard Simulcast Modulation of an Input Signal is only used to test the receivers of vehicular (mobile) and handheld (portable) equipment. The modulation shall be the manufacturer’s choice of one of the following modulations:

a) Linear Simulcast Modulation (LSM)

LSM modulation is a form of differential Quadrature Phase Shift Keying (QPSK) where each successive symbol is shifted in phase from its predecessor by multiples of 45 degrees (π/4 radians). LSM is compatible with a QPSK demodulator as defined in **[R1]**. LSM is related to CQPSK in that it modulates both the carrier phase and carrier amplitude. LSM uses a different filter function than the Nyquist Raised Cosine Filter defined in the CAI standard.

The LSM modulator consists of In Phase and Quadrature Phase (I and Q) amplitude modulators which modulate two carriers with the Q phase



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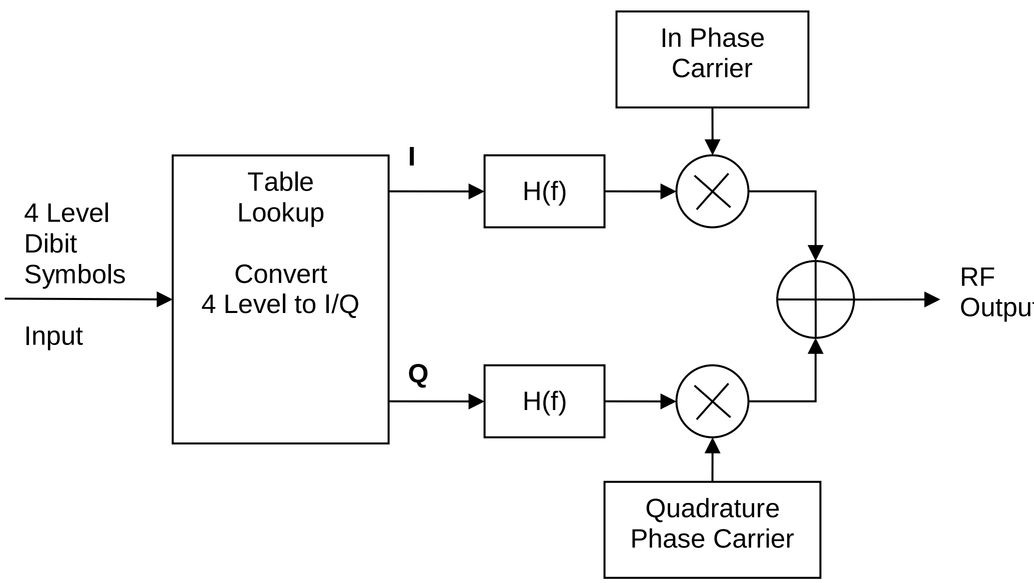
delayed from the I phase by 90 degrees. The I and Q modulators are driven by the filtered output of a 5-level signal which is derived from the Information Bits defined in the CAI standard in the same way as defined for CQPSK modulation.

The Information Bits are processed as defined in Table 9-2 of the CAI standard to yield a 5-level I signal and a 5-level Q signal. The I and Q signals are filtered with the LSM Filter Function described in the following paragraph. The I signal is then multiplied by the carrier and the Q signal is multiplied by the carrier after it has been delayed by 90 degrees. The modulated I and Q carriers are then summed together to yield the modulator output. The following block diagram defines the processing:




The filter function H(f) for LSM is a Gaussian filter cascaded with a lowpass filter. The Gaussian filter is down 3 dB at 2040 Hz. The impulse response in the time domain is conveniently expressed by the function g(t) as follows.

$$g(t) = \exp[-(2\pi\, f_{3dB}\, t)^2 / (2 \ln(2))]$$

where:

$f_{3dB}$ = 2040 Hz

The lowpass filter is down 3dB at 6200 Hz.



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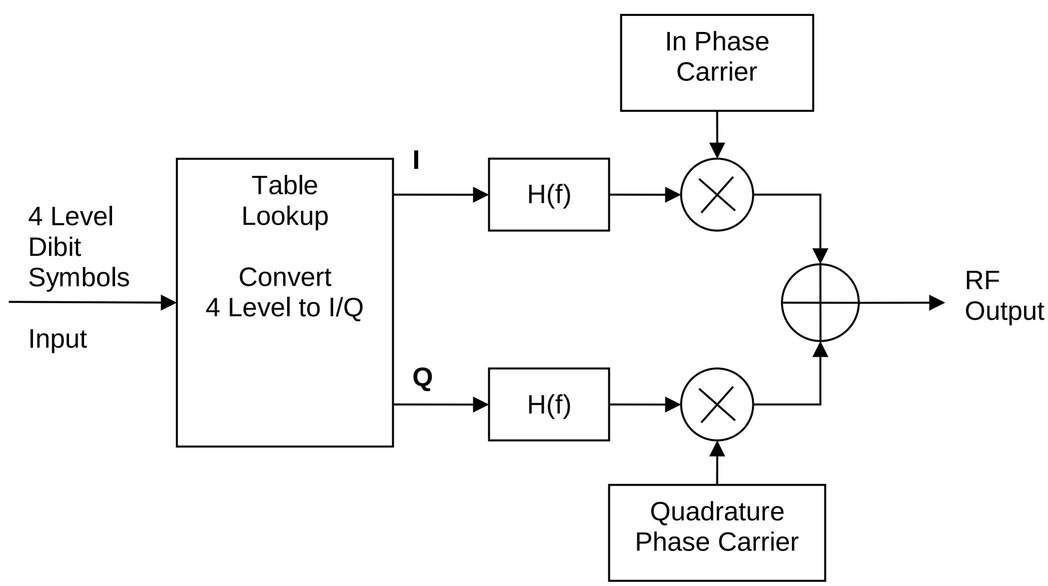
b) WCQPSK

WCQPSK modulation is a form of differential Quadrature Phase Shift Keying (QPSK) and is similar to CQPSK modulation **([R1]**, paragraph 9.5) except the Inphase (I) and Quadrature (Q) raised cosine filters have different characteristics. The modulation is compatible with all QPSK-C radio receivers.

The WCQPSK modulator consists of In Phase and Quadrature Phase (I and Q) amplitude modulators which modulate two carriers with the Q phase delayed from the I phase by 90 degrees. The I and Q modulators are driven by the filtered output of a 5-level signal which is derived from the Information Bits defined in the CAI standard in the same way as defined for CQPSK modulation.

The Information Bits are processed as defined in Table 9-2 of the CAI standard to yield a 5-level I signal and a 5-level Q signal. The I and Q signals are filtered with the WCQPSK Filter Function described in the following paragraph. The I signal is then multiplied by the carrier and the Q signal is multiplied by the carrier after it has been delayed by 90 degrees. The modulated I and Q carriers are then summed together to yield the modulator output. The following block diagram defines the processing:




The magnitude response of the filter is given approximately by the following formula.



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|H(f)| = magnitude response of the Raised Cosine Filter
|H(f)| = 0.5 + 0.5 cos(π f / 7200) for |f| ≤ 7200 Hz
|H(f)| = 0 for |f| > 7200 Hz

where:

f = frequency in Hz

### 1.4.3.7 Standard Symbol Patterns

The standard symbol patterns consist of two sequences of bits. The first sequence corresponds to the RF modulation, and the second sequence corresponds to a second output used for synchronous triggering and timing measurements. The sequences can be of arbitrary length. Each hexadecimal character in these tables represents two successively transmitted symbol, or di-bit levels. The Substitution Table gives the symbol levels to be transmitted for each hexadecimal value. The symbols are transmitted from the top left of the table to the bottom right. The symbol defined as "sym1" is transmitted before the symbol defined as "sym2". These tables give only the transmit symbol levels; the Common Air Interface defines the pulse shaping and deviation required.

Symbol Substitution Table

| Modulated Symbols | | | Second Output | |
|---|---|---|---|---|
| Input | sym1 | sym2 | sym1 | sym2 |
| 0 | +1 | +1 | 0 | 0 |
| 1 | +1 | +3 | 0 | 1 |
| 2 | +1 | -1 | not used | |
| 3 | +1 | -3 | not used | |
| 4 | +3 | +1 | 1 | 0 |
| 5 | +3 | +3 | 1 | 1 |
| 6 | +3 | -1 | not used | |
| 7 | +3 | -3 | not used | |
| 8 | -1 | +1 | not used | |
| 9 | -1 | +3 | not used | |
| A | -1 | -1 | not used | |
| B | -1 | -3 | not used | |
| C | -3 | +1 | not used | |
| D | -3 | +3 | not used | |
| E | -3 | -1 | not used | |
| F | -3 | -3 | not used | |



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a) Standard Tone Test Pattern:

This test pattern yields a 1011 Hz tone at reference level at the receiver vocoder.

```
Standard Tone Test Pattern Symbol Table
Modulation

557 5F5 FF7 7FF 293 554    7BC B19 4D0 DCE 24A 124
0D4 33C 0BE 1B9 184 4FC    C16 296 276 0E4 E24 A10
90D 433 C0B E1B 918 44C    FC1 629 627 60E C00 000
000 003 892 849 0D4 33C    02F 86E 461 13F C16 294
89D 839 000 000 001 C38    24A 124 350 CF0 2F8 6E4
184 4FF 058 A58 9D8 3B0    000 000 007 0E2 4A1 240
D43 3C0 BE1 B91 844 FF0    162 962 760 E6D E5D 548
ADE 389 284 90D 433 C08    F86 E46 113 FC1 629 624
D83 BA1 41C 2D2 BA3 890    A12 435 0CF 02F 86E 460
44F F05 8A5 89D 839 4C8    FB0 235 A4E 24A 124 350
33C 0BE 1B9 184 4FF 058    296 276 0EC 000 000 00C
892 849 0D4 33C 0BE 1B8    461 13F C16 296 276 0E4

557 5F5 FF7 7FF 293 AB8    A4E FB0 9A8 ACE 24A 124
0D4 33C 0BE 1B9 184 4FC    C16 296 276 0EC E24 A10
90D 433 C0B E1B 918 44C    FC1 629 627 60E 400 000
000 003 892 849 0D4 33C    02F 86E 461 13F C16 294
89D 83B 000 000 000 038    24A 124 350 CF0 2F8 6E4
184 4FF 058 A58 9D8 390    000 000 000 0E2 4A1 240
D43 3C0 BE1 B91 844 FF0    162 962 760 EE0 E00 000
000 389 284 90D 433 C08    F86 E46 113 FC1 629 624
D83 9AE 8B4 8B6 493 890    A12 435 0CF 02F 86E 460
44F F05 8A5 89D 83B 9A8    F4F 1FD 60E 24A 124 350
33C 0BE 1B9 184 4FF 058    296 276 0E4 000 000 00C
892 849 0D4 33C 0BE 1B8    461 13F C16 296 276 0EC
```



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b) Standard Silence Test Pattern:

This test pattern yields a silent output at the receiver vocoder.

```
    Standard Silence Test Pattern Symbol Table
    Modulation

557 5F5 FF7 7FF 293 554    7BC B19 4D0 DDB 10B A14
DE2 E82 693 63D 981 F98    F88 EC6 2B8 011 B10 BA0
5DE 2E8 269 363 D98 1F8    6F8 8EC 62B 801 800 000
000 006 C42 E85 DE2 E80    9A4 D8F 660 7E6 F88 EC4
8AE 004 000 000 001 C6C    10B A17 78B A09 A4D 8F4
981 F9B E23 B18 AE0 060    000 000 007 1B1 0BA 174
E2E 826 936 3D9 81F 9BC    88E C62 B80 12D E5D 548
ADE 6C4 2E8 5DE 2E8 268    4D8 F66 07E 6F8 8EC 628
E00 6A1 41C 2D2 BA6 C40    BA1 778 BA0 9A4 D8F 660
1F9 BE2 3B1 8AE 004 4C8    FB0 235 A5B 10B A17 788
E82 693 63D 981 F9B E20    EC6 2B8 018 000 000 018
C42 E85 DE2 E82 693 63C    660 7E6 F88 EC6 2B8 010

557 5F5 FF7 7FF 293 AB8    A4E FB0 9A8 ADB 10B A14
DE2 E82 693 63D 981 F98    F88 EC6 2B8 019 B10 BA0
5DE 2E8 269 363 D98 1F8    6F8 8EC 62B 801 000 000
000 006 C42 E85 DE2 E80    9A4 D8F 660 7E6 F88 EC4
8AE 006 000 000 000 06C    10B A17 78B A09 A4D 8F4
981 F9B E23 B18 AE0 040    000 000 000 1B1 0BA 174
E2E 826 936 3D9 81F 9BC    88E C62 B80 1A0 E00 000
000 6C4 2E8 5DE 2E8 268    4D8 F66 07E 6F8 8EC 628
E00 4AE 8B4 8B6 496 C40    BA1 778 BA0 9A4 D8F 660
1F9 BE2 3B1 8AE 006 9A8    F4F 1FD 61B 10B A17 788
E82 693 63D 981 F9B E20    EC6 2B8 010 000 000 018
C42 E85 DE2 E82 693 63C    660 7E6 F88 EC6 2B8 018
```



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c) Standard Interference Test Pattern:

This test pattern yields a silence output at the receiver vocoder and is balanced to have approximately equal positive and negative signal deviations.

```
    Standard Interference Test Pattern Symbol Table
    Modulation

557 5F5 FF7 7FF 8A2 540    FF8 BAA 959 E5A 18B A16
5E2 282 AB3 E0D 581 7A8    E80 FC6 0B8 011 A18 BA2
55E 228 2AB 3E0 D58 178    AE8 0FC 60B 801 800 002
000 006 862 E85 5E2 280    AAC F83 560 5EA E80 FC6
82E 004 000 A8A 9A8 568    18B A15 788 A0A ACF 836
581 7AB A03 F18 2E0 068    A6A 9AA 6A9 9A1 8BA 156
E22 82A B3E 0D5 817 AB8    80F C60 B80 10E FDE FCE
E49 686 2E8 55E 228 2A8    CF8 356 05E AE8 0FC 60A
E00 6B0 847 08E C26 860    BA1 578 8A0 AAC F83 562
17A BA0 3F1 82E 004 DEC    775 B91 6DA 18B A15 78A
282 AB3 E0D 581 7AB A00    FC6 0B8 018 2A0 C2A 0DA
862 E85 5E2 282 AB3 E0C    560 5EA E80 FC6 0B8 012

557 5F5 FF7 7FF 8A2 AAC    20A F03 421 95A 18B A16
5E2 282 AB3 E0D 581 7A8    E80 FC6 0B8 019 A18 BA2
55E 228 2AB 3E0 D58 178    AE8 0FC 60B 801 285 2A2
08E 0E6 862 E85 5E2 280    AAC F83 560 5EA E80 FC6
82E 006 A14 A80 8E0 E68    18B A15 788 A0A ACF 836
581 7AB A03 F18 2E0 048    852 A02 383 9A1 8BA 156
E22 82A B3E 0D5 817 AB8    80F C60 B80 1A0 E00 002
000 686 2E8 55E 228 2A8    CF8 356 05E AE8 0FC 60A
E00 407 3D3 C7F F06 860    BA1 578 8A0 AAC F83 562
17A BA0 3F1 82E 006 694    C82 6A4 B9A 18B A15 78A
282 AB3 E0D 581 7AB A00    FC6 0B8 010 2A0 C2A 0DA
862 E85 5E2 282 AB3 E0C    560 5EA E80 FC6 0B8 01A
```



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d) Standard Busy Test Pattern:

This pattern provides channel busy information.

Standard Busy Test Pattern Symbol Table
Modulation

```
557 5F5 FF7 7FF 293 555    7BC B19 4D0 DCE 24A 125
0D4 33C 0BE 1B9 184 4FD    C16 296 276 0E4 E24 A11
90D 433 C0B E1B 918 44D    FC1 629 627 60E C00 001
000 003 892 849 0D4 33D    02F 86E 461 13F C16 295
89D 839 000 000 001 C39    24A 124 350 CF0 2F8 6E5
184 4FF 058 A58 9D8 3B1    000 000 007 0E2 4A1 241
D43 3C0 BE1 B91 844 FF1    162 962 760 E6D E5D 549
ADE 389 284 90D 433 C09    F86 E46 113 FC1 629 625
D83 BA1 41C 2D2 BA3 891    A12 435 0CF 02F 86E 461
44F F05 8A5 89D 839 4C9    FB0 235 A4E 24A 124 351
33C 0BE 1B9 184 4FF 059    296 276 0EC 000 000 00D
892 849 0D4 33C 0BE 1B9    461 13F C16 296 276 0E5

557 5F5 FF7 7FF 293 AB9    A4E FB0 9A8 ACE 24A 125
0D4 33C 0BE 1B9 184 4FD    C16 296 276 0EC E24 A11
90D 433 C0B E1B 918 44D    FC1 629 627 60E 400 001
000 003 892 849 0D4 33D    02F 86E 461 13F C16 295
89D 83B 000 000 000 039    24A 124 350 CF0 2F8 6E5
184 4FF 058 A58 9D8 391    000 000 000 0E2 4A1 241
D43 3C0 BE1 B91 844 FF1    162 962 760 EE0 E00 001
000 389 284 90D 433 C09    F86 E46 113 FC1 629 625
D83 9AE 8B4 8B6 493 891    A12 435 0CF 02F 86E 461
44F F05 8A5 89D 83B 9A9    F4F 1FD 60E 24A 124 351
33C 0BE 1B9 184 4FF 059    296 276 0E4 000 000 00D
892 849 0D4 33C 0BE 1B9    461 13F C16 296 276 0ED
```



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e) Standard Idle Test Pattern:

This pattern provides channel idle information.

```
    Standard Idle Test Pattern Symbol Table
    Modulation

557 5F5 FF7 7FF 293 557    7BC B19 4D0 DCE 24A 127
0D4 33C 0BE 1B9 184 4FF    C16 296 276 0E4 E24 A13
90D 433 C0B E1B 918 44F    FC1 629 627 60E C00 003
000 003 892 849 0D4 33F    02F 86E 461 13F C16 297
89D 839 000 000 001 C3B    24A 124 350 CF0 2F8 6E7
184 4FF 058 A58 9D8 3B3    000 000 007 0E2 4A1 243
D43 3C0 BE1 B91 844 FF3    162 962 760 E6D E5D 54B
ADE 389 284 90D 433 C0B    F86 E46 113 FC1 629 627
D83 BA1 41C 2D2 BA3 893    A12 435 0CF 02F 86E 463
44F F05 8A5 89D 839 4CB    FB0 235 A4E 24A 124 353
33C 0BE 1B9 184 4FF 05B    296 276 0EC 000 000 00F
892 849 0D4 33C 0BE 1BB    461 13F C16 296 276 0E7

557 5F5 FF7 7FF 293 ABB    A4E FB0 9A8 ACE 24A 127
0D4 33C 0BE 1B9 184 4FF    C16 296 276 0EC E24 A13
90D 433 C0B E1B 918 44F    FC1 629 627 60E 400 003
000 003 892 849 0D4 33F    02F 86E 461 13F C16 297
89D 83B 000 000 000 03F    24A 124 350 CF0 2F8 6E7
184 4FF 058 A58 9D8 393    000 000 000 0E2 4A1 243
D43 3C0 BE1 B91 844 FF3    162 962 760 EE0 E00 003
000 389 284 90D 433 C0B    F86 E46 113 FC1 629 627
D83 9AE 8B4 8B6 493 893    A12 435 0CF 02F 86E 463
44F F05 8A5 89D 83B 9AB    F4F 1FD 60E 24A 124 353
33C 0BE 1B9 184 4FF 05B    296 276 0E4 000 000 00F
892 849 0D4 33C 0BE 1BB    461 13F C16 296 276 0EF
```



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f) Calibration Test Pattern:

In some cases it may be desirable to calibrate a BER measurement device with a signal of known BER. The following test pattern is derived from the standard tone test pattern by inverting every 20th bit, to yield 172 errors out of 3456 bits, for a 4.977% BER. This may be used for calibration purposes.

```
    Calibration Test Pattern Symbol Table
    Modulation

557 5E5 FF7 6FF 292 554    7AC B19 5D0 DCF 24A 134
0D4 23C 0BF 1B9 194 4FC    D16 297 276 0F4 E24 B10
90C 433 C1B E1B 818 44D    FC1 639 627 70E C01 000
010 003 992 848 0D4 32C    02F 96E 460 13F C06 294
99D 838 000 010 001 D38    24B 124 340 CF0 3F8 6E5
184 4EF 058 B58 9D9 3B0    010 000 107 0E3 4A1 250
D43 2C0 BE0 B91 854 FF0    062 963 760 E7D E5D 448
ADF 389 294 90D 533 C09    F86 E56 113 EC1 628 624
D93 BA1 51C 2D3 BA3 880    A12 535 0CE 02F 87E 460
54F F04 8A5 88D 839 5C8    FB1 235 A5E 24A 024 351
33C 0AE 1B9 084 4FE 058    286 276 1EC 001 000 01C
892 949 0D5 33C 0AE 1B8    561 13E C16 286 276 1E4

556 5F5 FE7 7FF 393 AB9    A4E FA0 9A8 BCE 24B 124
0C4 33C 1BE 1B8 184 4EC    C16 396 277 0EC E34 A10
80D 432 C0B E0B 918 54C    FC0 629 637 60E 500 001
000 013 892 949 0D5 33C    03F 86E 561 13E C16 284
89D 93B 001 000 010 038    34A 125 350 CE0 2F8 7E4
185 4FF 048 A58 8D8 391    000 010 000 1E2 4A0 240
D53 3C0 AE1 B90 844 FE0    162 862 761 EE0 E10 000
100 388 284 91D 433 D08    F87 E46 103 FC1 729 625
D83 9BE 8B4 9B6 492 890    A02 435 1CF 02E 86E 470
44F E05 8A4 89D 82B 9A8    E4F 1FC 60E 25A 124 250
33D 0BE 1A9 184 5FF 059    296 266 0E4 100 001 00C
882 849 1D4 33D 0BE 1A8    461 03F C17 296 266 0EC
```



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g) Automatic Frequency Control Test Pattern:

This test pattern yields a 1011 Hz tone at reference level at the receiver vocoder with the status bits set to inbound channel idle, s(1) = 1, s(0) = 1.

```
Automatic Frequency Control Test Pattern Symbol Table
Modulation

557 5F5 FF7 7FF 293 557    7BC B19 4D0 DCE 24A 127
0D4 33C 0BE 1B9 184 4FF    C16 296 276 0E4 E24 A13
90D 433 C0B E1B 918 44F    FC1 629 627 60E C00 003
000 003 892 849 0D4 33F    02F 86E 461 13F C16 297
89D 839 000 000 001 C3B    24A 124 350 CF0 2F8 6E7
184 4FF 058 A58 9D8 3B3    000 000 007 0E2 4A1 243
D43 3C0 BE1 B91 844 FF3    162 962 760 E6D E5D 54B
ADE 389 284 90D 433 C0B    F86 E46 113 FC1 629 627
D83 BA1 41C 2D2 BA3 893    A12 435 0CF 02F 86E 463
44F F05 8A5 89D 839 4CB    FB0 235 A4E 24A 124 353
33C 0BE 1B9 184 4FF 05B    296 276 0EC 000 000 00F
892 849 0D4 33C 0BE 1BB    461 13F C16 296 276 0E7

557 5F5 FF7 7FF 293 ABB    A4E FB0 9A8 ACE 24A 127
0D4 33C 0BE 1B9 184 4FF    C16 296 276 0EC E24 A13
90D 433 C0B E1B 918 44F    FC1 629 627 60E 400 003
000 003 892 849 0D4 33F    02F 86E 461 13F C16 297
89D 83B 000 000 000 03B    24A 124 350 CF0 2F8 6E7
184 4FF 058 A58 9D8 393    000 000 000 0E2 4A1 243
D43 3C0 BE1 B91 844 FF3    162 962 760 EE0 E00 003
000 389 284 90D 433 C0B    F86 E46 113 FC1 629 627
D83 9AE 8B4 8B6 493 893    A12 435 0CF 02F 86E 463
44F F05 8A5 89D 83B 9AB    F4F 1FD 60E 24A 124 353
33C 0BE 1B9 184 4FF 05B    296 276 0E4 000 000 00F
892 849 0D4 33C 0BE 1BB    461 13F C16 296 276 0EF
```



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### 1.4.3.8 Second Output Patterns

a) Trigger On Start Of Link Data Unit 1 (LDU1):

This pattern provides a trigger at the start of Link Data Unit 1 (LDU1).

```
    Trigger on Start of LDU1 Pattern
    Second Output

400 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000

000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
```



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b) No Trigger:

This pattern provides no trigger.

```
    No Trigger
    Second Output

000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000

000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
```



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c) Trigger On Start Of Link Data Unit 2 (LDU 2):

This pattern provides a trigger at the start of Link Data Unit 2 (LDU 2).

```
Trigger on Start of LDU 2 Pattern
Second Output

000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000

400 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
```

### 1.4.3.9 Rated Audio Frequency Output Power

The rated audio frequency output power is the power specified by the manufacturer that, under standard conditions, is available at the receiver output terminals when the latter are connected to a specified load.

When measuring equipment under nonstandard environmental conditions, the rated audio frequency output power may be degraded by no more than 3 dB from the value specified at standard conditions.



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### 1.4.3.10 Audio Frequency Output Load

For equipment with an integral audio frequency output transducer, the load is the output transducer.

NOTE: The manufacturer shall specify the method of connection and state the impedance (and tolerance) of the output transducer at 1000 Hz. It is desirable also to state the impedance at specified upper and lower audio frequency band limits.

An audio frequency output test load is an impedance network that replaces the load to which the receiver is connected under normal operating conditions. It simulates the impedance of the normal load and any cables with which it is normally used. The network is specified by the manufacturer and usually consists of a pure resistance.

### 1.4.3.11 Standard Bit Error Rate (BER)

Bit error rate (BER) is the ratio, expressed as a percentage, of received bit errors to the total number of bits transmitted. The value of the standard bit error rate (BER) is 5%.

### 1.4.4 Definitions for Transmitters

This section details definitions for the characteristics and measurements of digital private land mobile transmitters in vehicular (mobile), fixed (base station), or handheld (portable) installations.

### 1.4.4.1 Standard Transmitter Load

The Standard Transmitter Load shall consist of one of the following:

For transmitters with non-integral antennas:
A nonradiating resistive attenuator (see 1.5.13) with a 50 Ω input impedance (unless otherwise specified by the manufacturer) and an output impedance matched to the test equipment.

For transmitters with integral antennas:
The transmitter load shall be the antenna supplied by the manufacturer. The manufacturer shall specify the coupling or matching circuit from the integral antenna to the test equipment.



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### 1.4.4.2 Standard Transmitter Audio Modulation Input

The standard transmitter audio modulation input is pink noise sloped at -3 dB / octave, and band limited from 180 Hz to 3400 kHz.

### 1.4.4.3 Standard Transmitter Test Pattern

The standard transmitter test pattern is a continuously repeating 511 bit binary pseudo random bit sequence based on ITU-T O.153 (formerly CCITT V.52).

### 1.4.4.4 Standard Transmitter Symbol Rate Pattern

The standard transmitter symbol rate pattern is a continuously repeating bit stream as defined by the following:

01 01 11 11 01 01 11 11 ...

### 1.4.4.5 Standard Transmitter Low Deviation Pattern

The standard transmitter low deviation pattern is a continuously repeating bit stream as defined by the following:

10 10 00 00 10 10 00 00 ...

### 1.4.4.6 Standard Transmitter C4FM Modulation Fidelity Pattern

The standard transmitter C4FM modulation fidelity pattern is a continuously repeating bit stream as defined by the following 24 bit sequence:

01 01 11 00 00 01 10 01 11 10 11 11 ...

### 1.4.4.7 Standard Transmitter C4FM Modulation Fidelity Spectrum

The standard transmitter C4FM modulation fidelity spectrum is the ideal spectrum of the baseband modulating signal that is generated when the bit stream is the standard transmitter C4FM modulation fidelity pattern. The spectrum is described by the magnitude and phase of the spectral components at each of the frequencies listed in table 1.



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Table 1
C4FM Modulation Fidelity Spectrum

| k | Frequency (Hz) | Y(f) (Hz) | \|Y(f)\| (Hz) | arg[Y(f)] (degrees) |
|---|---|---|---|---|
| 1 | 400 | -323.30 -j856.16 | 915.16 | -110.69 |
| 2 | 800 | 942.48 -j181.38 | 959.77 | -10.89 |
| 3 | 1,200 | 888.58 -j444.29 | 993.46 | -26.57 |
| 4 | 1,600 | 362.76 -j1047.20 | 1,108.25 | -70.89 |
| 5 | 2,000 | 958.59 -j204.59 | 980.18 | -12.05 |
| 6 | 2,400 | -942.48 +j0.00 | 942.48 | -180.00 |
| 7 | 2,800 | 23.26 +j4.96 | 23.78 | 12.05 |

#### 1.4.4.8 Test Bandwidth

Test bandwidth is the measurement frequency range used for transmitter emission mask tests, and is derived from 47 CFR 90.209 and 47 CFR 90.210. Test bandwidth is centered about the assigned transmitter frequency, and is ±50 kHz from the edge of the FCC authorized bandwidth. The test bandwidth is as follows:

a) ±55.625 kHz for 12.5 kHz channel spacing below 896 MHz.

b) ±53.0 kHz for 6.25 kHz channel spacing below 896 MHz.

c) ±56.8 kHz for 12.5 kHz channel spacing for frequencies 896 to 901 MHz, and 935 to 940 MHz.

### 1.4.5 Definitions for Environmental Testing

#### 1.4.5.1 Degradation From Standard (DFS)

DFS is degradation from the TIA standard or the manufacturer's specification, whichever is more stringent. This is not a degradation from measured value.



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### 1.4.6 Definitions for Trunking

This section details definitions for the characteristics and measurements of digital private land mobile receivers and transmitters in vehicular (mobile), fixed (base station), or handheld (portable) installations. These definitions are predominantly for trunking signals to be used as test patterns for the measurements.

#### 1.4.6.1 Standard Signal Software

The definitions in this section rely on a software specification to generate test signals that comply with the trunking signal specifications defined in the TIA-102 series of documents. The software is contained in annex A (normative). The software is used to process signal specifications contained in the following sections so as to generate a dibit sequence that can be used to generate test signals. Trunking test signals are defined as Trunking Signaling Blocks, TSBKs.

#### 1.4.6.2 Standard RFSS Broadcast Signal

The standard RFSS broadcast signal is defined as a sequence of TSBKs that broadcast an Identifier Update (IDEN_UP), Network Status Broadcast (NET_STS_BCST), and RFSS Status Broadcast (RFSS_STS_BCST). These are designed to emulate an idle RFSS, in order to test subscriber radios. The parameters for TSBKs are variable, depending on the frequency band, channel spacing, slot size, system identity, etc. The signal given here is representative of a possible signal for the 806 MHz frequency band in the U.S. Other test signals are possible, and they are equally valid. The manufacturer should specify the test signal if it varies from this example.

**IDEN_UP**

| | |
|---|---|
| LB=0, P=0, Opcode=3D | |
| MFID=00 | standard value |
| Identifier=0 | |
| BW=0C8 | 25 kHz |
| TX Offset=1B4 | 45 MHz |
| Channel Space=0C8 | 25 kHz |
| Base Freq.=09 9B C1 44 | 161,202,500 for 806.0125 MHz |



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**NET_STS_BCST**

| | |
|---|---|
| LB=0, P=0, Opcode=3B | |
| MFID=00 | standard value |
| LRA=01 | |
| WACN ID=0 00 01 | |
| System ID=2 93 | =NAC |
| Channel=00 01 | second channel, 806.03125 MHz |
| Sys. Service Class=FD | all services |

**RFSS_STS_BCST**

| | |
|---|---|
| LB=1, P=0, Opcode=3A | |
| MFID=00 | standard value |
| LRA=01 | |
| System ID=2 93 | =NAC |
| RF Sub-Sys ID=01 | |
| Site ID=01 | |
| Channel=00 01 | second channel, 806.03125 MHz |
| Sys. Service Class=FD | all services |

```
OUTBOUND:  1
MICROSLOTS PER SLOT:  5
Control Channel Packet Data Unit #1:
FS       : 5575 f5ff 77ff
NID      : 2937           NAC = 293; DUID = 7
SS       : 2
TSBK #1:
OCTET 0 : 3D              LB = 0; P = 0; Opcode = 3D
MFID    : 00
OCTET 2 : 06
OCTET 3 : 46
OCTET 4 : D0
OCTET 5 : C8
OCTET 6 : 09
OCTET 7 : 9B
OCTET 8 : BC
OCTET 9 : 62
TSBK #2:
OCTET 0 : 3B              LB = 0; P = 0; Opcode = 3B
MFID    : 00
OCTET 2 : 01
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 12
OCTET 6 : 93
OCTET 7 : 00
OCTET 8 : 01
OCTET 9 : FD
TSBK #3:
OCTET 0 : BA              LB = 1; P = 0; Opcode = 3A
```



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```
MFID    : 00
OCTET 2 : 01
OCTET 3 : 02
OCTET 4 : 93
OCTET 5 : 01
OCTET 6 : 01
OCTET 7 : 00
OCTET 8 : 01
OCTET 9 : FD
```

The signal also uses a secondary output pattern to represent the slot boundaries for timing. This is a sequence of zero values with unit values coincident with the slot boundaries. The secondary output is given below.

```
000 000 000 000 000 001  000 000 000 000 000 000
000 000 000 000 000 000  000 000 000 000 000 000
000 000 000 000 000 000  000 000 000 000 000 001
000 000 000 000 000 000  000 000 000 000 000 000
000 000 000 000 000 000  000 000 000 000 000 000
```

### 1.4.6.3 Standard Service Request Signal

The standard service request signal is defined as a TSBK to request service from a system. The service request may vary depending on the type of service requested, and the type of service allowed by the system. The representative service request given here is a Group Voice call Request (GRP_V_REQ). Other test signals are possible, and they are equally valid. The manufacturer should specify the test signal if it varies from this example.

**GRP_V_REQ**

| | |
|---|---|
| LB=1, P=0, Opcode=00 | |
| MFID=0 | standard value |
| Service Options=04 | routine, nonprotected, half-duplex, default priority |
| Group Address=00 01 | |
| Source Address=00 00 01 | |

```
OUTBOUND:  0
MICROSLOTS PER SLOT:  1
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 2937           NAC = 293; DUID = 7
SS      : 2
TSBK #1:
OCTET 0 : 80             LB = 1; P = 0; Opcode = 00
MFID    : 00
OCTET 2 : 04
OCTET 3 : 00
```



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```
OCTET 4 : 00
OCTET 5 : 00
OCTET 6 : 01
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 01
```

A secondary test signal also applies a trigger output to indicate the start of the TSBK. The secondary signal is defined below.

```
100 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000
```

### 1.4.6.4 Standard Service Grant Signal

The standard service grant signal is defined as a TSBK to grant service from a system. It complements the standard service request signal. The complement to the GRP_V_REQ is the Group Voice Channel Grant (GRP_V_CH_GRANT). To facilitate timing, the grant signal is a single event that can be delayed for convenience by Queued Response signals (QUE_RSP). Consequently, two signals are defined, a QUE_RSP signal to postpone the grant, and then a GRP_V_CH_GRANT. Other test signals are possible, and they are equally valid. The manufacturer should specify the test signal if it varies from this example.

**QUE_RSP**

| | |
|---|---|
| LB=1, P=0, Opcode=21 | |
| MFID=00 | standard value |
| AIV=1, Service Type=00 | queued response to GRP_V_REQ |
| Reason Code=40 | channel resources not currently available |
| Call Options=04 | see service options for GRP_V_REQ |
| Group Address=00 01 | see talk group for GRP_V_REQ |
| Target Address=00 00 01 | see source address for GRP_V_REQ |

```
OUTBOUND:  1
MICROSLOTS PER SLOT:  5
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 2937           NAC = 293; DUID = 7
SS      : 2
TSBK #1:
OCTET 0 : 3D             LB = 0; P = 0; Opcode = 3D
MFID    : 00
OCTET 2 : 06
OCTET 3 : 46
OCTET 4 : D0
OCTET 5 : C8
OCTET 6 : 09
```



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```
OCTET 7 : 9B
OCTET 8 : BC
OCTET 9 : 62
TSBK #2:
OCTET 0 : 3B              LB = 0; P = 0; Opcode = 3B
MFID    : 00
OCTET 2 : 01
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 12
OCTET 6 : 93
OCTET 7 : 00
OCTET 8 : 01
OCTET 9 : FD
TSBK #3:
OCTET 0 : A1              LB = 1; P = 0; Opcode = 21
MFID    : 00
OCTET 2 : 80
OCTET 3 : 40
OCTET 4 : 04
OCTET 5 : 00
OCTET 6 : 01
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 01
```

**GRP_V_CH_GRANT**

| | |
|---|---|
| LB=1, P=0, Opcode=00 | |
| MFID=00 | standard value |
| Service Options=04 | see service options for GRP_V_REQ |
| Channel=00 28 | 41-st channel, 807.0125 MHz |
| Group Address=00 01 | see talk group for GRP_V_REQ |
| Source Address=00 00 01 | see source address for GRP_V_REQ |

```
OUTBOUND:  1
MICROSLOTS PER SLOT:  5
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 2937            NAC = 293; DUID = 7
SS      : 2
TSBK #1:
OCTET 0 : 3D              LB = 0; P = 0; Opcode = 3D
MFID    : 00
OCTET 2 : 06
OCTET 3 : 46
OCTET 4 : D0
OCTET 5 : C8
OCTET 6 : 09
OCTET 7 : 9B
OCTET 8 : BC
OCTET 9 : 62
```



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```
TSBK #2:
OCTET 0 : 3B            LB = 0; P = 0; Opcode = 3B
MFID    : 00
OCTET 2 : 01
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 12
OCTET 6 : 93
OCTET 7 : 00
OCTET 8 : 01
OCTET 9 : FD
TSBK #3:
OCTET 0 : 80            LB = 1; P = 0; Opcode = 00
MFID    : 00
OCTET 2 : 04
OCTET 3 : 00
OCTET 4 : 28
OCTET 5 : 00
OCTET 6 : 01
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 01
```

These signals also use a secondary output for timing measurements. The QUE_RSP signal does not cause a subscriber to respond, so a null secondary signal (i.e., all zeros) is used. The GRP_V_CH_GRANT signal has a signal coincident with the third TSBK. This is given below.

```
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 000 000 000 000 000
000 000 000 000 000 000   000 133 333 333 333 333
333 333 333 333 333 333   333 333 333 333 333 333
```

## 1.5 Standard Test Conditions

### 1.5.1 Basic Equipment Under Test

The equipment shall be assembled and any necessary adjustments shall be made in accordance with the manufacturer's instructions for the mode of operation being tested. When alternate modes of operation are available, the equipment shall be assembled and adjusted for these modes, as instructed by the manufacturer. A complete series of measurements shall be made for each mode of operation. For units equipped with encryption, tests shall be run in the clear (unencrypted) mode.



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### 1.5.2 Associated Equipment

Tests are to be made with associated equipment that is normally used with the unit under test installed.

In mobile or portable equipment, the receiver, transmitter, control unit, and power supply unit shall be included and functional in the housing(s) supplied with the equipment, where applicable.

In fixed equipment, the normal power supply unit and other units that might affect the operation shall be included and operational in the cabinet(s) supplied with the equipment, where applicable.

### 1.5.3 Special Function Subsystems

In cases where the equipment is provided with special function subsystems, the subsystems shall be disabled unless the method of measurement calls for these subsystems to be enabled.

### 1.5.4 Standard Conditions for the Power Supply

#### 1.5.4.1 General

The standard test voltage shall be specified by the manufacturer, and shall, unless otherwise specified, refer to the voltage at the power cable input of the equipment when the equipment is in operation. The voltage shall not deviate from the stated value by more than ±2% during the measurement of any one parameter, on any one unit under test, unless otherwise stated. If the manufacturer does not specify the standard test voltage, then the default value shall be used as given in Table 2.

#### 1.5.4.2 Default Standard Test Voltages for Battery Chemistry Types

Equipment measurements are typically conducted on battery powered equipment using a battery eliminator. Since each battery chemistry cell type has a unique voltage characteristic, it is appropriate to conduct measurements with the value based on the cell type and the number of cells utilized in the battery pack. Table 2 lists commonly available battery chemistry cell types. The values listed as Standard Test Voltages in Table 2 are to be used in combination with the number of cells in the battery to calculate the standard test voltage to be applied to the equipment by the battery eliminator for standard test conditions.



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Table 2
Secondary Cell Voltages for Common Battery Chemistry Types

| Cell Chemistry | Nominal Voltage<br><br>(V/Cell) | Default Standard Test Voltage<br><br>(V/Cell) |
|---|---|---|
| Lead Acid | 2.0 | Per Table 3 |
| Nickel-Cadmium with incorporated gas-venting | 1.2 | 1.40 |
| Nickel-Cadmium of the sealed type | 1.2 | 1.25 |
| Nickel-Metal-Hydride | 1.2 | 1.25 |
| Lithium Ion | 3.6 | 3.75 |

#### 1.5.4.3 Standard Test Voltage for Equipment Powered by Integral Batteries

For equipment powered by batteries integral to the equipment the standard test voltage shall be specified by the manufacturer or be equal to the default standard test voltage of Table 2, multiplied by the number of cells in the battery to be used. The standard test voltage shall not exceed the voltage measured at the battery at any time after 10% of rated battery capacity has been used.

For equipment with integral batteries, the battery may be disconnected or removed, and an external source connected through leads that are shielded and filtered. When making radiated measurements, the batteries may be disconnected, but not removed, to prevent altering the radiation or reception pattern of the unit.

Integral batteries are defined as battery packs that are required for a primary mode of operation and mounted integrally to the equipment. The battery pack or individual cells may be detachable or removable for the purpose of replacement by the user.

#### 1.5.4.4 Standard Test Voltage for Equipment Powered by External Batteries

For vehicular equipment powered by batteries external to the equipment, the standard test voltage shall be specified by the manufacturer, or be equal to the default standard test voltage of Table 3, based on the equipment current drain.



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Table 3
Vehicular 12 Volt Battery Default Standard Test Voltages

| Operating Current (A) | Test Voltage (V) |
| --- | --- |
| Less than 6 | 13.8 |
| 6 to 16 | 13.6 |
| 16 to 36 | 13.4 |
| 36 to 50 | 13.2 |
| Greater than 50 | 13.0 |

### 1.5.4.5 Other Power Sources

For operation from other power supplies or types of batteries, the manufacturer shall specify the nominal and extreme test voltages.

### 1.5.4.6 Standard AC Voltage and Frequency

The standard ac test voltage shall be equal to the nominal ac mains voltage to be applied to the equipment. If equipment is provided with different input voltage taps, the one designated nominal should be used. The standard test frequency shall be equal to the nominal ac mains frequency. During the measurements, the test frequency, and the test voltage shall not deviate more than ±2% from the value at the beginning of each test.

For power supplies that are specified as wide input range or universal input, the nominal ac mains voltage to be applied to the equipment shall be used under nominal test conditions. For extreme conditions testing, the upper and lower mains voltage, and frequency test values shall be calculated using the nominal ac mains values applied to the equipment.

Alternatively, the manufacturer shall specify the extreme conditions voltage and frequency values.



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### 1.5.5 Standard Atmospheric Conditions

The standard atmospheric condition is a temperature of 25 °C at an atmospheric pressure of 1013 hPa (1013 mbar). Measurements, however, may be carried out at any combination of temperature, pressure, and relative humidity within the following limits:

Temperature: 20 °C to 35 °C
Relative Humidity: 45% to 75%
Atmospheric Pressure: 860 hPa to 1060 hPa

During any series of tests, the temperature should be held to within ±1 °C.

If the quantities to be measured depend on temperature, humidity, or atmospheric pressure, and the law of dependence is known, the values obtained shall be corrected by calculation to the standard atmospheric condition. If the quantities to be measured depend on temperature, humidity, or atmospheric pressure, and the law of dependence is not known, the atmospheric conditions prevailing during the tests shall be recorded.

## 1.6 Characteristics of Test Equipment

Test equipment to be used is left to the manufacturer's discretion. All test equipment used shall be maintained and calibrated at least as often as recommended by the test equipment manufacturer. The following parameters are provided as a guide for selecting the test equipment.

### 1.6.1 Distortion and Audio Frequency Level Meter

For the measurement of distortion and audio level, the indicating meter shall be a true rms voltmeter. The meter shall have the following characteristics:

a) Input impedance of at least 50 kΩ.

b) Measurement accuracy of ±3% over the frequency range from 20 Hz to 20 kHz.

c) A selectable 3 dB audio pass band from ≤50 Hz to ≥30,000 Hz.

d) Accurately measure nonsinusoidal signals with a peak-to-rms ratio of at least 3:1.

e) An optional low pass filter may be used for measurement of receivers



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employing Class-D audio amplifiers. If used, the corner frequency shall be ≥ 15 kHz.

The rms meter may be a separate device or it may be included within a distortion factor meter.

The distortion factor meter shall incorporate a band rejection filter to attenuate the fundamental component of the demodulated signal. The filter shall have the following characteristics:

a) The relative attenuation of the fundamental frequency shall be at least 40 dB.

b) The relative attenuation at 1/2 or twice the fundamental frequency shall not exceed 0.6 dB.

c) In the presence of a noise signal, the filter shall not cause more than 1 dB of relative attenuation of the total noise output power of a 300 Hz to 3000 Hz bandwidth flat noise source.

d) Provide an output signal of the waveform after it has been processed by the notch.

e) Provide for manual tuning of the notch, or fixed notch frequency after automatic nulling.

### 1.6.2 RF Digital Modulated Signal Generators

The RF digital modulated signal generator shall have the following characteristics:

a) 50 Ω output impedance with a VSWR of ≤1.2:1.

b) Calibrated variable output with a level accuracy of ≤ ±1 dB.

c) Single sideband phase noise in a 1 Hz bandwidth of 120 dB below the carrier at 12.5 kHz offset from the carrier.

d) The C4FM signals may be generated by means of an IQ modulator driven by an IQ waveform or a digital C4FM modulator driven by a data file.

IQ waveform generation: The IQ waveform shall be generated using a mathematical representation of the C4FM modulator defined in **[R1]** clause



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9.4 using a filter length not to exceed 32 symbols. The input data file to the C4FM modulator simulator shall be the Standard Symbol Patterns of 1.3.3.7.

Digital waveform generation: The digital C4FM modulator may be implemented in the signal generator using software or hardware or a combination of both to represent the C4FM modulator per **[R1]** clause 9.4 using a filter length not to exceed 32 symbols. The input data file to the digital modulator shall be the Standard Symbol Patterns of 1.3.3.7.

e) When generating the Standard Interference Test Pattern, the adjacent channel power measured in a 6 kHz bandwidth offset 12.5 kHz above or below the carrier frequency, as measured per the procedure of clause 2.2.8, shall be between 71 dB and 77 dB.

f) Modulation of C4FM, CQPSK, or standard simulcast modulation. (Certain tests for 12.5 kHz channel spaced equipment will require C4FM modulation. Also, certain tests for 6.25 kHz channel spaced equipment will require CQPSK modulation. Certain tests will require standard simulcast modulation.)

g) The intermodulation in the signal generators and the combining network may be tested, when performing the receiver intermodulation rejection test, using the following procedure:

   1) Insert a variable attenuator between the combining network and the receiver under test.

   2) Increase the attenuation in steps of 1 dB and increase the output voltage of the generators by the same amounts, thus maintaining the original signal level input to the receiver.

   3) Since the intermodulation products in the output should remain constant, any increase is caused by intermodulation in the signal generators or combining network. Therefore, more isolation between the signal generators or an improved combining network is required.

h) An auxiliary output signal that is derived from the frequency reference of the signal generator.

i) Short term frequency stability of less than $10^{-8}$/day.



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### 1.6.3 Test Pattern Generator

The test pattern generator is a device that provides a digital test pattern to the RF digital modulated signal generator. It shall:

a) Provide two independent outputs that are time synchronous. Filtering on each output shall be identical to provide equal signal delay in both paths.

b) Provide an output to work in conjunction with the RF digital modulated signal generator to produce a C4FM, CQPSK, or standard simulcast modulation modulated signal with the desired test pattern.

c) Provide a second output to be used for synchronization of time measurements.

d) Be able to switch from one set of pattern outputs to another set of pattern outputs, such that the end of the first set of patterns is followed synchronously by the beginning of the second set of patterns.

### 1.6.4 RF Frequency Modulated Signal Generator

The RF frequency modulated signal generator shall have the following characteristics:

a) 50 Ω output impedance with a VSWR of ≤1.2:1.

b) Calibrated variable output with a level accuracy of ≤ ±1 dB.

c) Single sideband phase noise in a 1 Hz bandwidth of 120 dB below the carrier at 12.5 kHz offset from the carrier.

NOTE: The measurement of certain characteristics, for example adjacent channel rejection, can be erroneous when a signal generator having a high spectral noise content is used. At frequencies below 200 MHz, a crystal filter having at least 20 dB rejection at the adjacent channel can be connected at the output of the signal generator under test as a means of assessing whether a result is influenced by signal generator noise.

d) Variable frequency deviation with an uncertainty of less than 5%.

e) The intermodulation in the signal generators and the combining network may be tested, when performing the receiver intermodulation rejection test,



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using the following procedure:

1) Insert a variable attenuator between the combining network and the receiver under test.

2) Increase the attenuation in steps of 1 dB and increase the output voltage of the generators by the same amounts, thus maintaining the original signal level input to the receiver.

3) Since the intermodulation products in the output should remain constant, any increase is caused by intermodulation in the signal generators or combining network. Therefore, more isolation between the signal generators or an improved combining network is required.

### 1.6.5 Digital Multimeter

The digital multimeter (DMM) shall have the following characteristics:

a) ac/dc voltage-measurement accuracy of ≤ ±2% of reading.

b) ac/dc current-measurement accuracy of ≤ ±2% of reading.

c) Input impedance of ≥ 1 MΩ.

d) ac frequency response 100 Hz to 20 kHz.

e) ac rms responding.

f) Accurately measure nonsinusoidal signals with a peak to rms ratio of 4:1.

### 1.6.6 RF Power Meter

The RF power meter shall have the following characteristics:

a) Measurement accuracy of ≤ ±0.2 dB.

b) Input VSWR of ≤1.2:1 over the frequency range of the measurement.

c) Average responding.

d) For CQPSK measurements, have at least a 20 ms time averaging.



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### 1.6.7 Spectrum Analyzer

The spectrum analyzer shall have the following characteristics:

a) Resolution bandwidth range of ≤100 Hz to 1 MHz in a 1, 3, 5, 10 sequence by decades. The resolution bandwidth filter shape factor (ratio of 60 dB bandwidth to 3 dB bandwidth) should be ≤15.

b) Video bandwidth range of ≤300 Hz to 3 MHz in a 1, 3, 10 sequence by decade.

c) Log fidelity error of ≤2 dB over a 70 dB range.

d) A spurious free dynamic range of ≥80 dB.

e) Ability to measure relative levels of input-signal components with an accuracy of ≤ ±1 dB.

f) A quasipeak detector that meets the requirements of CISPR Publication 11, and a peak detector, as required in the method of measurement.

### 1.6.8 Standard Receiver

The standard receiver shall consist of a receiver configured to comply with the requirements of the receiver section of this document.

### 1.6.9 Adjacent Channel Power Analyzer

This instrument shall be similar to the spectrum analyzer previously described except it shall also be capable of:

a) Directly measuring (in linear power units) and displaying in average power density (not video averaging) in three channels as a function of swept frequency over user defined channels by digital computation.

b) Making the measurement using a resolution bandwidth in the range from 0.5% to 2% of the measurement bandwidth.

c) Adjustable band edge settings (-6 dB point) with at least 100 Hz resolution.

d) Having optional band edge markers simultaneously visible for a center channel and both adjacent channels.



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e) Displaying the power in the center channel (in dBm), and the ratio of the power in each adjacent channel (in dB) relative to the center channel.

f) Having a frequency span display range of 100 kHz, 50 kHz, and 30 kHz.

g) Providing an output signal to generate a print, plot, or file of the display and readings.

### 1.6.10 Audio Frequency Load

An audio frequency output test load is an impedance network that replaces the load to which the receiver is connected under normal operating conditions. It simulates the impedance of the normal load and any cables with which it is normally used. The network is specified by the manufacturer, and usually consists of a pure resistance. It must have the capability to dissipate the receiver audio output power without generating a temperature rise that would change its operating impedance.

### 1.6.11 Frequency Counter

The frequency counter shall have the following characteristics:

a) Time drift of $\leq 1 \times 10^{-9}$ parts per day.

b) Resolution ≤1 Hz.

c) Capable of counting audio frequencies with a resolution of ≤0.001 Hz.

d) Calibrated to an absolute frequency accuracy 10 times better than the desired measurement accuracy.

### 1.6.12 Oscilloscope

The oscilloscope shall have the following characteristics:

a) Measure time intervals with an accuracy of ≤ ±2%.

b) Measure peak voltage with an accuracy of ≤ ±1%.

c) An external trigger input.

d) Dual vertical channel operation.



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e) A digital storage scope capable of viewing trace information that occurs 10 ms before the trigger. Capable of viewing trace information that occurs up to 200 ms after the trigger with a resolution of 1 ms per division.

f) Horizontal sweep control for 1 μs to 100 ms per division.

g) Vertical sensitivity of 5 mV to 5 V per division.

h) Bandwidth of at least 10 MHz.

### 1.6.13 RF Attenuator

The RF attenuator is a two-port resistive device that couples a portion of the transmitter's output power to the test equipment. The attenuated power has the same waveform as the transmitter's output power. The attenuator shall have the following characteristics:

a) RF frequency range of 10 times the transmitter's assigned frequency.

b) Attenuation that will reduce the transmitter's output power to the optimum range of the test equipment.

c) Attenuation over the range indicated in a) shall be flat within ±1 dB.

d) Power rating of ≥2 times the output power of the transmitter under test.

e) VSWR over the range indicated in a) shall be ≤1.2:1.

### 1.6.14 Audio Noise Generator

The audio noise generator shall have the following characteristics:

a) Either a flat frequency spectrum ±1 dB from 20 Hz to 3 kHz and ±3 dB from 10 Hz to 5 kHz, or a band limited pink noise spectrum consisting of pink noise sloped at -3 dB per octave from 20 Hz to 20 kHz cascaded with a filter to limit the pass band from 180 Hz to 3400 Hz.

b) Amplitude roll-off of at least 12 dB/octave above 5 kHz.

c) Output level sufficient to provide nominal microphone input level.

d) Peak to rms ratio of at least 4:1.



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### 1.6.15 Sound Level Meter

The sound level meter shall conform to ANSI S1.4-1983 standard.

### 1.6.16 RF Detector

The RF detector shall have the following characteristics at the assigned transmitter frequency:

a) Provide a linear response from RF input to detected output voltage.

b) Time constant of ≤0.5 ms.

c) RF frequency range sufficient to detect the transmitter's output power.

d) Input VSWR of ≤1.2:1.

e) Provide for the ability to add in an additional time constant of 1.5 ms ±0.5 ms.

### 1.6.17 Directional Coupler

The directional coupler shall have the following characteristics:

a) Insertion loss of ≤1 dB at the RF frequency of the transmitter ±500 kHz.

b) Directivity of ≥20 dB.

c) VSWR for all ports of ≤1.2:1.

### 1.6.18 50 Ohm Termination

The 50 ohm terminations are used to terminate unused directional coupler and combining network ports in their characteristic impedances. The 50 ohm termination shall have the following characteristics:

a) VSWR of ≤1.01:1.

b) Frequency range and power rating as required by the test.



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### 1.6.19 Transmitter Key Control Switch

The transmitter key control switch is defined as a device or circuit that supplies the power necessary to change the transmitter state from standby to transmit and supplies a piece of test equipment with a simultaneous trigger signal. For example, a TX key control switch may be a relay contact or a saturated transistor that supplies a voltage to an oscilloscope trigger input and the push-to-talk (PTT) input of the transmitter.

### 1.6.20 Dummy Microphone

The dummy microphone circuit shall be specified by the manufacturer. Its purpose is to provide a frequency response characteristic that can replace the microphone during testing. It shall have a constant input impedance over the frequency range of 20 Hz to 5000 Hz.

### 1.6.21 RF Combining Network

An RF combining network is used to couple two or more RF signals together for making measurements. The RF combining network shall have the following characteristics:

a) No more than 0.5 dB imbalance in attenuation between any input port and the output port.

b) VSWR of ≤1.3:1 at any port, with all other ports terminated with a 50 Ω termination.

### 1.6.22 Notch Filter

The notch filter shall have the following characteristics:

a) Attenuation of ≥30 dB at the transmitter's assigned frequency.

b) Attenuation of ≤2 dB at frequencies ≥2 times the transmitter's assigned frequency.

c) An input and output VSWR of ≤1.2:1.



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### 1.6.23 Lumped Constant Line Stretcher (LCLS)

a) A typical LCLS may consist of the following circuit with the values from table 4:

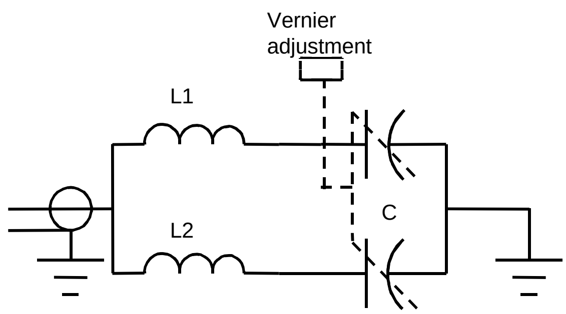


Table 4
Component Values

| Frequency (MHz) | L1 (nH) | L2 (nH) | C (pF) |
|---|---|---|---|
| 25-33 | ≈113 | ≈554 | 10-365 pF Dual Gang Variable Capacitor |
| 33-42 | ≈69 | ≈410 | |
| 42-50 | ≈44 | ≈290 | |
| 130-150 | ≈33 | ≈123 | 5.9-50 pF Butterfly Capacitor |
| 150-175 | ≈25 | ≈83 | |

b) The minimum VSWR of the LCLS box should be ≥10 times that of the test VSWR.

### 1.6.24 Constant Impedance Line Stretcher (CILS)

The constant impedance line stretcher shall have the following characteristics:

a) Insertion loss ≤0.1 dB at the RF frequency of the transmitter ±500 kHz.

b) Phase rotation of 360 degrees at RF frequencies >175 MHz.



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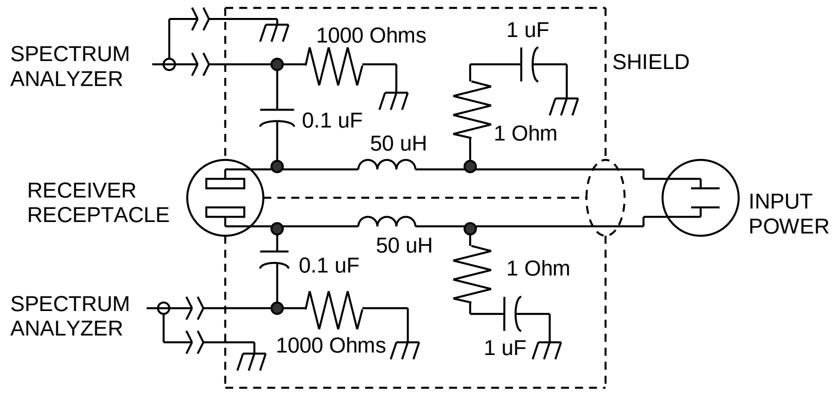
### 1.6.25 Line Impedance Stabilization Network (LISN)

a) The LISN shall consist of the following circuit:




### 1.6.26 Variable dc Power Supply

The variable dc power supply shall have the following characteristics:

a) Variable dc voltage over a range of standard test voltage -20% to standard test voltage +20%.

b) Maximum current sufficient to supply the transmitter when keyed.

c) Ripple and noise of ≤10 mV rms.

d) Operate in the constant voltage mode.

### 1.6.27 Variable ac Power Supply

The variable ac power supply shall have the following characteristics:

a) Variable ac voltage over a range of standard test voltage -20% to standard test voltage +20%.

b) Maximum current sufficient to supply the equipment under test when the transmitter is keyed and under full load and power output conditions.

c) Capable of operating in a constant voltage mode.

d) Shall produce a line frequency of ±1% of the assigned line frequency.



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### 1.6.28 Standard Radiation Test Site (3 meter)

The test site shall be on a level surface that is of uniform electrical characteristics. The site shall be clear of metal objects, overhead wires, etc., and shall be as free as possible from undesired signals such as ignition noise, other carriers, etc. The distance from the unit under test or the test antenna to reflecting objects shall not be less than 3 m. At the transmitter or receiver end, a turntable essentially flush with the ground should be provided that can be remotely controlled. A platform 80 cm high shall be provided on this turntable to hold the receiver or transmitter under test. A conductive ground plane consisting of not greater than 1.3 cm square soldered mesh wire shall extend to or beyond the two 3 m radius circles described above. If desired, radome shelters may be provided for the equipment and personnel at both ends of the test site. All such construction shall be of wood, plastic, or nonmetallic material. All power, telephone, or control circuits to the site shall be placed below the conductive ground plane.

Measurements of radiated signals shall be made at a point 3 m from the center of the turntable. A nonconductive pole with a movable horizontal boom shall be arranged so that the center of the test antenna can be raised and lowered from 1 m to 6 m. The test antenna shall be mounted to the end of the boom with its cable lying horizontally on the boom back to the supporting mast. A spectrum analyzer is connected to this cable at the foot of the mast.

The transmitter or receiver to be tested shall be placed on the platform on the turntable. (Rack type equipment may be placed directly on the turntable.) The power cable shall extend downward to a maximum of 0.1 m above the ground plane. Any excess cable shall be coiled on the turntable. For receiver tests, a vertical whip antenna, adjusted to 1/4 wavelength at the standard input signal frequency, mounted 3 m above the ground plane over the center of the turntable, having a ground system of at least four ground radials 1/4 wavelength long, shall be connected to the receiver antenna terminal. A minimum length of low loss cable shall be used to make this connection.

### 1.6.29 Standard Radiation Test Site (30 meter)

The test site shall be on level ground that is of uniform electrical characteristics. The site shall be clear of metal objects, overhead wires, etc., and shall be as free as possible from undesired signals such as ignition noise, other carriers, etc. The distance from the unit under test or the test antenna to reflecting objects such as rain gutters, house plumbing, etc. shall not be less than 90 m. At the transmitter or receiver end, a turntable essentially flush with the ground should be provided that can be remotely controlled. A platform 80 cm high shall be provided on this turntable to hold the receiver or transmitter under test. If desired, radome shelters may be provided for the equipment and personnel at both ends of the test site. All



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such construction shall be of wood, plastic, or nonmetallic material. All power, telephone, or control circuits to the site shall be buried at least 0.3 m deep.

Measurements of radiated signals shall be made at a point 30 m from the center of the turntable. A nonconductive pole with a movable horizontal boom shall be arranged so that the center of the test antenna can be raised and lowered from 1 m to 6 m. The test antenna shall be mounted on the end of the boom with its cable lying horizontally on the boom back to the supporting mast. A spectrum analyzer is connected to this cable at the foot of the mast.

The transmitter or receiver to be tested shall be placed on the platform on the turntable. (Rack type equipment may be placed directly on the turntable.) The power cable shall extend downward to a maximum of 0.1 m above the ground plane. Any excess cable shall be coiled on the turntable. For receiver tests, a vertical whip antenna, adjusted to 1/4 wavelength at the standard input signal frequency, mounted 3 m above the ground plane over the center of the turntable, having a ground system of at least four ground radials 1/4 wavelength long, shall be connected to the receiver antenna terminal. A minimum length of low loss cable shall be used to make this connection.

NOTE: This site is recommended when making measurements below 88 MHz. If the 3 meter site is used for these measurements the results will be worse than the actual values.

### 1.6.30 Acoustic Chamber

The acoustic chamber shall be constructed using ISO 3745 Annex A as a guide.

When performing acoustic measurements, the nonreflectivity of the environment can be checked by observing a 6 dB change on the sound level meter for a l:2 change in distance to the acoustic transducer.

### 1.6.31 Modulation Fidelity Measuring System

The modulation fidelity measuring system shall have the following characteristics:

a) Tunable over the applicable range of radio frequencies.

b) Capable of capturing at least a 144 symbol segment of a transmitted waveform.

c) Capable of measuring carrier frequency offset to within ±10 Hz.



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d) Capable of measuring frequency deviation at the sample points to within 50 Hz.

e) Capable of measuring rms deviation error at the sample points to within 5%.

f) Capable of demodulating signals with levels -18 dBm to +36 dBm.

### 1.6.32 Bit Error Rate Detector

The bit error rate detector shall have the following characteristics:

a) Capable of comparing an arbitrary input signal pattern to a resulting time delayed output pattern.

b) Capable of displaying bit error rate in the range of 0.004% to 10%.

In some cases it may be desirable to test the calibration of the bit error rate detector. For this purpose the calibration test pattern may be used. The bit error rate detector shall display a value of 4.977% BER when the calibration test pattern is compared to the standard tone test pattern.

### 1.6.33 Faded Channel Simulator

The faded channel simulator shall have the following characteristics:

a) Capable of operation at the desired channel frequency.

b) Simulate a flat fading channel for simulated vehicle speeds of 8 km/h to 300 km/h.

c) Simulate two rays with independent fading statistics. Each Rayleigh faded ray shall have a time delay of up to 200 μs with delay resolution of 0.1 μs.

d) Generation of the Rayleigh fading conditions shall conform to the following:

e) The measured Rayleigh Cumulative Probability Distribution Function (CPDF) shall be compared against a calculated CPDF. The calculated Rayleigh CPDF, $F(P)$, is as follows:

for $P<0$: $F(P) = 0$



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for $P \geq 0$: $F(P) = 1 - \exp(-P/P_{ave})$

where

$P$ is the signal power level and $P_{ave}$ is the mean power level.

Measured CPDF of power shall be within ±1 dB of the calculated CPDF of power for 9 dB above the mean power level to 20 dB below the mean power level.

Measured CPDF of power shall be within ±5 dB of the calculated CPDF of power for 20 dB below the mean power level to 30 dB below the mean power level.

f) The Level Crossing Rate (LCR) shall be compared against a calculated LCR. The calculated Rayleigh level crossing rate, L(P), is as follows:

for $P<0$: $L(P) = 0$

for $P \geq 0$: $L(P) = (2\pi P/P_{ave})^{0.5} f_d \exp(-P/P_{ave})$

where

$P$ is the signal power level, $P_{ave}$ is the mean power level, and $f_d$ is the Doppler frequency offset associated with the simulated vehicle speed. The Doppler frequency is given by the following:

$f_d = (v/c)f_c$

where

$v$ is the simulated vehicle speed, $c$ is the speed of light in a vacuum ($2.997925 \times 10^8$ m/s), and $f_c$ is the assigned channel frequency.

The measured LCR curve shall not deviate from the calculated LCR curve by more than ±10% of the simulated vehicle speed. This shall hold for 3 dB above the mean power level to 30 dB below the mean power level.

g) The measured power spectral density, $S(f)$, shall meet the requirements specified below. The power spectrum measurement shall be made on an unmodulated carrier (frequency $f_c$) applied to the input of the channel simulator.



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The maximum power spectral density level, $S_{max}$, shall exceed $S(f_c)$ by at least 6 dB.

The simulated Doppler frequency offset, $f_d$, shall be within ±5% of the theoretical Doppler frequency offset associated with the vehicle speed. The simulated Doppler frequency offset shall be calculated from the measured power spectral density as follows:

$$f_d = (1/2\pi)(2b_2/b_0)^{0.5}$$

where

$$b_n = (2\pi)^n \int_0^\infty S(f)(f - f_c)^n \, df$$

$b_n$ is the $n^{th}$ moment of $S(f)$.

$S(f)$ shall be at least 30 dB below $S(f_c)$ for $|f - f_c| > 2f_d$.

h) The correlation coefficient of the wrapped phase of the simulated, received signal shall be compared against the calculated theoretical correlation coefficient of the phase of the Rayleigh faded signal. The theoretical correlation coefficient, $\rho(\tau)$, is approximated by the following:

$$\rho(\tau) = \frac{3}{2\pi}\sin^{-1}\big(h(\tau)\big) + 6\left(\frac{1}{2\pi}\sin^{-1}\big(h(\tau)\big)\right)^2 - \frac{3}{4\pi^2}\sum_{n=1}^{\infty}\frac{\big(h(\tau)\big)^{2n}}{n^2}$$

where

$$h(\tau) = J_0(2\pi f_d \tau) * \ (2 f_d)\frac{\sin(2\pi f_d \tau)}{2\pi f_d \tau}$$

and * is the convolution function.

The measured correlation coefficient of the phase shall be 0.8 ±0.1 at a lag of $0.05/f_d$, and 0.5 ±0.1 at a lag of $0.15/f_d$.

Note 1: The wrapped phase is the phase angle obtained by computing the



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phase of the vector in x-y Cartesian coordinates that represents the in-phase and quadrature-phase amplitude of the carrier at any instant in time. This angle is often computed with a 4-quadrant arctangent function. A convenient example of one such function is the atan2(x,y) function in most spreadsheet programs.

Note 2: The convolution given in equation (8) for $h(\tau)$ can further be simplified. To evaluate the convolution in the time domain, the Fourier transform can be applied to each function. The Fourier transforms in the frequency domain can be multiplied. The result can then be transformed back into the time domain.

The Fourier transform of $(2f_d)\dfrac{\sin(2\pi f_d\tau)}{2\pi f_d\tau}$ is

1 for $|f| \le f_d$
0 for $|f| > f_d$

The Fourier transform of $J_0(2\pi f_d\tau)$ is

$1/[\pi f_d (1 - f^2/f_d^2)^{1/2}]$ for $|f| \le f_d$
0 for $|f| > f_d$

The product of the two transforms is thus

$1/[\pi f_d (1 - f^2/f_d^2)^{1/2}]$ for $|f| \le f_d$
0 for $|f| > f_d$

Taking the inverse Fourier transform yields the following:

$$h(\tau) = J_0(2\pi f_d\tau)$$

i) Spurious outputs of the faded channel simulator shall be lower than 50 dB below the desired signal.

### 1.6.34 FM Demodulator

The FM demodulator shall have the following characteristics:

a) Capable of operation at the desired channel frequency.

b) Provide an output voltage proportional to the instantaneous frequency deviation of an FM signal, with a throughput delay of <1 ms.



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c) Output distortion of <1.0%.

d) Demodulator 3 dB bandwidth of ≤15 Hz to ≥15 kHz.

e) Capable of selecting a low pass filter after the demodulator with a 3 dB cut-off frequency of 3 kHz.

f) Capture effect sufficient to cause a suppression of a 1 kHz tone by at least 10 dB for a signal 10 dB below an unmodulated carrier, and 30 dB for a signal 30 dB below an unmodulated carrier. The test method is as follows:

1) Connect two signal generators through an RF combining network to the FM demodulator input.

2) With one signal generator turned off, adjust the level of the second generator to 40 dB below the maximum input level of the FM demodulator. Modulate this generator with 1 kHz tone at 12.5 kHz deviation.

3) Record the resulting output from the FM demodulator output.

4) Adjust the output of the second signal generator to 30 dB below the maximum input level of the FM demodulator. This signal generator shall be unmodulated.

5) Record the resulting output from the FM demodulator. The output must be lower than 10 dB below the level recorded in step 3).

6) Increase the level of the unmodulated signal generator to 10 dB below the maximum input level of the FM demodulator.

7) Record the resulting output from the FM demodulator. The output must be lower than 30 dB below the level recorded in step 3).

### 1.6.35 FFT Based Spectrum Analyzer

The FFT based spectrum analyzer shall have the following characteristics:

a) Measurement frequency range of 0 to 10 kHz.

b) Dynamic range ≥60 dB.



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c) Magnitude and phase accuracy of $\leq$5%.

### 1.6.36 RF Decoder and Protocol Analyzer

The RF decoder and protocol analyzer shall have the following characteristics:

a) Be able to decode RF signals for the frequency band of interest.

b) Be able to decode and interpret data fields and conditions, such as slot boundaries, status bits, channel grants, tone test patterns, etc.

### 1.6.37 Modulation Domain Analyzer

The modulation domain analyzer shall have the following characteristics:

a) Measure frequency with a resolution of 1 kHz or less over the frequency range of interest.

b) An external trigger input or multiple channels with RF envelope detector trigger capability on one of the channels.

c) Horizontal sweep control for 1 μs to 100 ms per division.

d) Ability to assign a time stamp to the occurrence of the trigger signal and display time-of-measurement.

e) Have time markers and frequency markers to allow set-up of a mask for the resultant waveform display.

### 1.6.38 RF Anechoic Chamber

A RF anechoic chamber is one in which all interior surfaces are covered by electromagnetic absorption material that suppresses reflections to simulate free-space conditions. A free-space environment is assured by the chamber providing a square law site attenuation characteristic. Both the equipment to be tested and the measurement antenna are located in the chamber interior. The chamber must be sufficiently large to assure that their separation assures far-field test conditions at the lowest frequency of measurement. Like an open-air test site (OATS), these may be custom designs in contrast to being off-the-shelf available. The chamber may be constructed of shielding material to exclude external disturbing influences.



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An example RF anechoic chamber with the dimensions 5-m x 5-m x 10-m has the following performance characteristics:

| **Characteristic** | **Performance** |
|---|---|
| Useful Frequency Range | 100 MHz to above 1 GHz |
| Useful Measuring Distance | 3-m to 5-m |
| Nominal Site Attenuation | 26 dB (5-m separation at 100 MHz) |
| Nominal Site Attenuation | 46 dB (5-m separation at 1 GHz) |
| Minimum Shielding Attenuation | 60 dB |
| Minimum Return Loss of Absorbers | 10 dB |
| Maximum Equipment Size | 1-m |

### 1.6.39 Gigahertz Transverse Electromagnetic Cell (GTEM)

The GTEM cell consists of a section of gently flared rectangular coaxial transmission line terminated with a matched load. The end termination of the cell is a wall with absorbing material. At low frequencies it operates as a circuit element 50 Ohm load. At higher frequencies absorbers attenuate the incident waves as in an anechoic chamber. The GTEM cell shall have the following characteristics:

a) Radiated frequency range from 9 kHz to 5 GHz.

b) Input impedance ($Z_c$) 50Ω.

c) VSWR of ≤1.65:1.

d) Shielding effectiveness of 80dB.

e) Field uniformity ±3dB below 1GHz and ±4dB above 1 GHz.

f) Maximum continuous wave (CW) input power of 1 kW.

g) Antenna factor $E = e_0 \sqrt{P} = e_0 V_{out} / \sqrt{50}$

where:



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$e_0 = \sqrt{Z_c} / h$

$E$ is the electrical field strength in the test volume
$h$ is the height of the septum in the test volume
$e_0$ is the output voltage from the septum

h) The equipment under test manipulator reflections should not affect accuracy by more than ±2 dB.

i) Signal processor software: IEC 60481-1 compliant 3 axis (or greater) correlation algorithm that converts maximum individual dBμV field strength, including provisions to utilize correlation factors obtained via measurements at an open air test site.



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# 2. METHODS OF MEASUREMENT

## 2.1 Methods of Measurement for Receivers

This section details test definitions and methods of measurement of the characteristics of digital private land mobile receivers in vehicular (mobile), fixed (base station), or handheld (portable) installations employing C4FM, CQPSK, or a linear simulcast modulation, with or without a vocoder, with or without encryption.

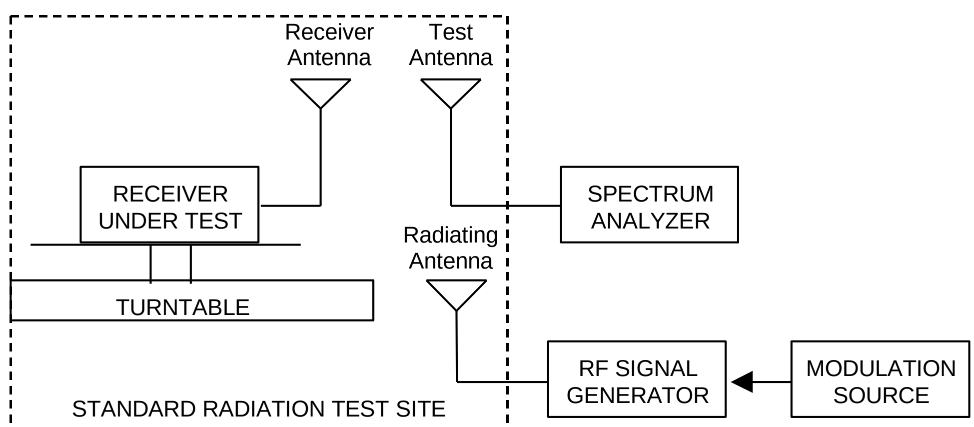
When the receivers are equipped with one or more special function subsystems, the subsystems shall be disabled. This section (2.1) does not cover testing of receivers that include subsystems that cannot be disabled or bypassed.

### 2.1.1 Radiated Spurious Output Power

2.1.1.1 Definition

The radiated spurious output power is the electromagnetic power generated or amplified in a receiver and radiated from the receiver or by the antenna, or by all control, audio, and power leads.

2.1.1.2 Method of Measurement (Using an Open Air Test Site)




a) Adjust the equipment in accordance with the manufacturer's tuning procedure. Measurements are to be done at a standard radiation test site, or an FCC listed test site compliant with ANSI C63.4-2001 clause 5.4 using a spectrum analyzer with a quasi-peak detector meeting the requirements of



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IEC CISPR Publication 16.

b) Adjust the signal generator to the signal frequency, modulated with the standard tone test pattern, adjusted for a level 10 dB above the minimum level that produces normal receiver operation.

c) For each spurious frequency of measurement, adjust the test antenna for the correct length. This length may be determined from a calibration ruler that is supplied with the equipment. For a superheterodyne receiver not controlled by a digital device, these measurements shall be made from 30 MHz to 1000 MHz, or 2 times the highest local oscillator frequency generated in the receiver, whichever is higher. For a superheterodyne receiver controlled by a digital device, the upper limit test frequency shall be the greater of the requirement for a receiver not controlled by a digital device, or an upper limit frequency per table 5:

Table 5
Test Frequency Limits

| Highest Internally Generated Digital Device Operating Frequency (MHz) | Upper Limit Test Frequency (MHz) |
|---|---|
| Below 108 | 1000 |
| 108 to 500 | 2000 |
| 500 to 1000 | 5000 |
| Above 1000 | 5th Harmonic of highest internally generated digital device operating frequency |

d) For each frequency, raise and lower the test antenna to obtain the maximum reading on the spectrum analyzer with the test antenna at a horizontal polarity. Exclude any responses caused by the RF signal generator.

e) Rotate the turntable for a maximum reading on the spectrum analyzer.

f) Repeat steps d) and e) to obtain a maximum reading. Record this power level.

g) Repeat steps d) and e) with the antenna vertically polarized. Record this power level. (When the test antenna length does not permit lowering the



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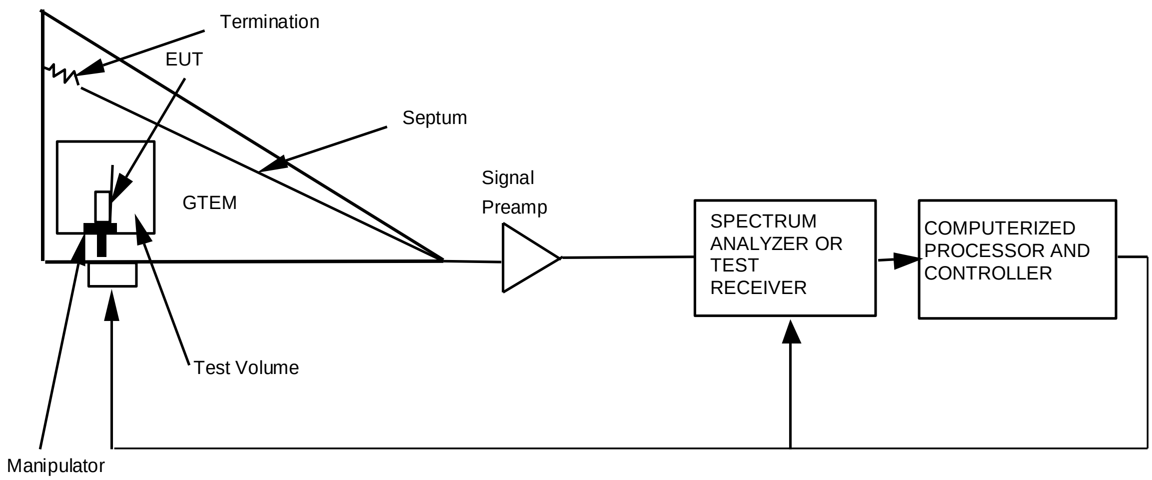
boom to 1 m, adjust the minimum height for 0.3 m ground clearance).

h) Compute the field intensity in μV/m of the larger of the readings obtained in steps f) and g), using the information supplied with the test antenna to make this conversion, accounting for cable loss.

i) The radiated spurious output power at each frequency of measurement is the value obtained in step h) at the frequency of measurement. It is not necessary to record levels that are more than 20 dB below the specified limit.

2.1.1.3 Alternate Method of Measurement (Using a GTEM Cell)




a) Position the equipment under test in the GTEM cell test volume. The initial orientation shall be designated as the X orientation. Designate additional orthogonal orientations Y and Z.

b) Set the spectrum analyzer or test receiver to use an IEC CISPR 16 quasi-peak detector for signals below 1 GHz, or an average detector above 1 GHz. Sweep or scan the appropriate frequency range and record the voltage from the GTEM at each spurious radiation frequency observed.

c) Repeat step b) for the Y and Z orientations.

d) Use the GTEM calibration software to determine the maximum field intensity in dB μV/m at each spurious frequency.

e) The radiated spurious output power at each frequency is the value obtained



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in step d).

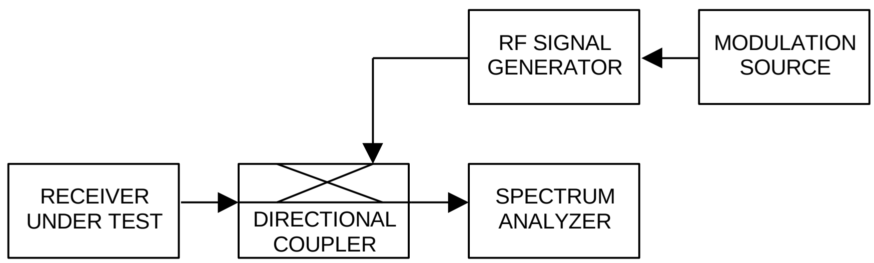
Note: For purposes for receiver FCC Certification per Part 15 rules, it is required that that the GTEM be calibrated to an open air test site using the method in 2.1.1.2 and inputting the appropriate correlation factors into the signal processing software.

### 2.1.2 Conducted Spurious Output Power

2.1.2.1 Definition

The conducted spurious output power is power that is generated or amplified in a receiver and appears at the receiver's antenna terminals.

2.1.2.2 Method of Measurement




a) Connect a spectrum analyzer, using a quasi-peak detector meeting the requirements of IEC CISPR Publication 16, (through a resistive matching network if required to match the receiver input impedance Rn to the spectrum analyzer) to the receiver antenna terminals, through a directional coupler.

b) Couple in a signal generator on the receiver frequency, modulated with the standard tone test pattern, adjusted for a level 10 dB above the minimum level that produces normal receiver operation.

c) Tune the spectrum analyzer to search for spurious outputs. For a superheterodyne receiver not controlled by a digital device, these measurements shall be made from 30 MHz to 1000 MHz, or 2 times the highest local oscillator frequency generated in the receiver, whichever is higher. For a superheterodyne receiver controlled by a digital device, the upper limit test frequency shall be the greater of the requirement for a receiver not controlled by a digital device, or an upper limit frequency per table 6:



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Table 6
Test Frequency Limits

| Highest Internally Generated Digital Device Operating Frequency (MHz) | Upper Limit Test Frequency (MHz) |
|---|---|
| Below 108 | 1000 |
| 108 to 500 | 2000 |
| 500 to 1000 | 5000 |
| Above 1000 | 5th Harmonic of highest internally generated digital device operating frequency |

Record all spurious outputs found, except any responses caused by the RF signal generator.

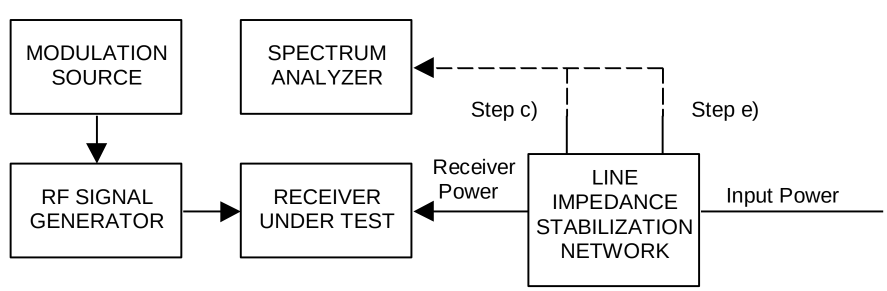
d) The conducted spurious output power is the largest reading obtained in step c) (corrected for any matching network loss, if used).

### 2.1.3 Power Line Conducted Spurious Output Voltage

2.1.3.1 Definition

The power line conducted spurious output voltage is voltage that is generated or amplified in a receiver and appears between each power line terminal that connects to a public utility line and ground.

2.1.3.2 Method of Measurement




a) Connect the receiver to the power line through a line impedance stabilization network as illustrated.



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b) Adjust the signal generator to the signal frequency, modulated with the standard tone test pattern, adjusted for a level 10 dB above the minimum level that produces normal receiver operation.

c) Connect a spectrum analyzer, using a quasi peak detector meeting the requirements of IEC CISPR Publication 16, of nominal 50 Ω impedance to one terminal of the line impedance stabilization network.

d) Tune the spectrum analyzer to search for spurious outputs from 150 kHz to 30 MHz. Record all spurious outputs found, except any responses caused by the RF signal generator.

e) Connect the spectrum analyzer to the other terminal of the line impedance stabilization network and repeat step d).

f) Repeat step d) using the spectrum analyzer in an average responding mode.

g) Repeat step e) using the spectrum analyzer in an average responding mode.

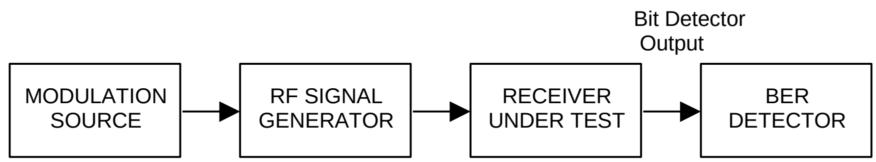
h) The power line conducted spurious output voltage at each frequency is reading obtained in steps d), e), f), and g).

### 2.1.4 Reference Sensitivity

2.1.4.1 Definition

The reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation that will result in the standard BER at the receiver detector.

2.1.4.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal, with the standard tone test pattern, to the receiver input terminals.

c) Connect a bit error rate detector to the bit detector output of the receiver.



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d) Adjust the level of the input signal to achieve standard bit error rate (BER) when measured over at least a 250 ms time interval. Record the level of the signal generator.

e) Repeat step d) with the input signal modulated with standard simulcast modulation.

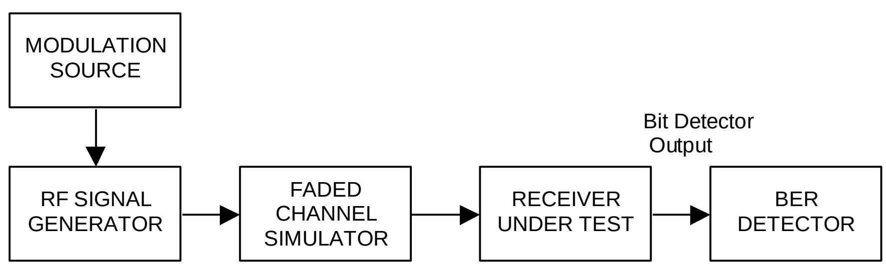
f) The reference sensitivities are the signal generator levels obtained in step d) and step e).

### 2.1.5 Faded Reference Sensitivity

2.1.5.1 Definition

The faded reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation that, when applied through a faded channel simulator, will result in the standard BER at the receiver detector.

2.1.5.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals, with the standard test tone pattern, through a faded channel simulator.

c) Adjust the faded channel simulator for a single path flat Rayleigh fade corresponding to a vehicle speed of 8 km/h.

d) Connect a bit error rate detector to the bit detector output of the receiver.

e) Adjust the level of the input signal to achieve standard bit error rate (BER) when measured over a time interval of at least *t* seconds, where *t* is defined by the following:



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$t = 180{,}000 / ( (F_{\mathrm{MHz}}) (S_{\mathrm{km/h}}) )$

where

$F_{\mathrm{MHz}}$ is the receiver operating frequency in MHz
$S_{\mathrm{km/h}}$ is the vehicle speed in km/h.

Record the level of the signal generator.

f) Repeat step e) with the faded channel simulator set for a single path flat Rayleigh fade corresponding to a vehicle speed of 100 km/h.

g) Repeat steps e) and f) with the input signal modulated with standard simulcast modulation.

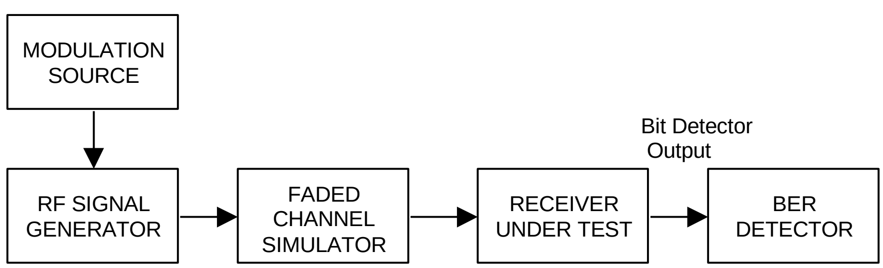
h) The faded reference sensitivities are the signal generator levels recorded in steps e), f), and g).

### 2.1.6 Signal Delay Spread Capability

2.1.6.1 Definition

The signal delay spread capability is the amount of delay between two independently faded equal amplitude signals, when the standard input signal is applied through a faded channel simulator, that will result in the standard BER at the receiver detector. The channel simulator provides a composite signal of two equal amplitude independently faded rays, the last of which is a delayed version of the first.

2.1.6.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals, with the standard test tone pattern, through a faded channel simulator.



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c) Adjust the faded channel simulator to provide a two equal ray composite signal with independent Rayleigh fading corresponding to a Doppler frequency of 30 Hz, where the Doppler frequency is given by the following:

$$f_d = (v/c)f_c$$

where

$v$ is the simulated vehicle speed, $c$ is the speed of light in a vacuum ($2.997925 \times 10^8$ m/s), and $f_c$ is the assigned channel frequency.

d) Connect a bit error rate detector to the bit detector output of the receiver.

e) Adjust the delay between the two rays to achieve the standard bit error rate when measured over a time interval of at least 10 seconds. Record the delay between the two rays.

f) Repeat steps c), d), and e) with the input signal modulated with standard simulcast modulation.

g) The delay recorded in step e) is the signal delay spread capability for standard modulation, and the result obtained in step f) is the signal delay spread capability for standard simulcast modulation.

### 2.1.7 Adjacent Channel Rejection

#### 2.1.7.1 Definition

The adjacent channel rejection is the ratio of the level of an unwanted input signal to the reference sensitivity. The unwanted signal is of an amplitude that causes the BER produced by a wanted signal 3 dB in excess of the reference sensitivity to be reduced to the standard BER. The digital adjacent channel rejection is a measure of rejection of an unwanted signal that has a digital modulation. The digital simulcast adjacent channel rejection is a measure of rejection of an unwanted signal that has standard simulcast modulation.



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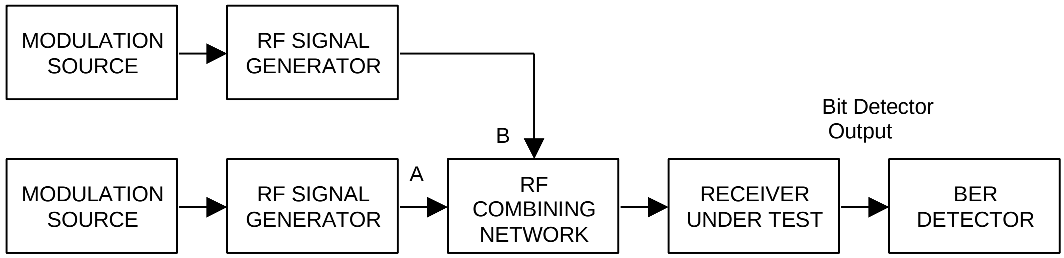
2.1.7.2 Method of Measurement for Digital Adjacent Channel Rejection




a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network, modulated with the standard tone test pattern. Reduce its level to obtain reference sensitivity. Record this level in dBm as $P_{\mathrm{REF}}$.

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted C4FM input signal for 12.5 kHz channel spaced equipment, or a CQPSK input signal for 6.25 kHz channel spaced equipment, modulated with the standard interference test pattern to terminal B of the combining network. The modulation of this generator shall be uncorrelated to the modulation of the generator attached to terminal A.

e) Adjust the unwanted signal frequency to the adjacent channel frequency above and below the wanted signal frequency. Adjust the unwanted signal level each time to reestablish the standard BER. Record these levels in dBm as $P_{\mathrm{HIGH}}$ and $P_{\mathrm{LOW}}$ .

f) Calculate the digital adjacent channel rejection by the following:

*digital adjacent channel rejection high* = $P_{\mathrm{HIGH}} - P_{\mathrm{REF}}$

*digital adjacent channel rejection low* = $P_{\mathrm{LOW}} - P_{\mathrm{REF}}$

The smaller of the above is the digital adjacent channel rejection.

g) Repeat steps d) and e) above with the unwanted input signal modulated with standard simulcast modulation.

h) Calculate the digital simulcast adjacent channel rejection by the following:



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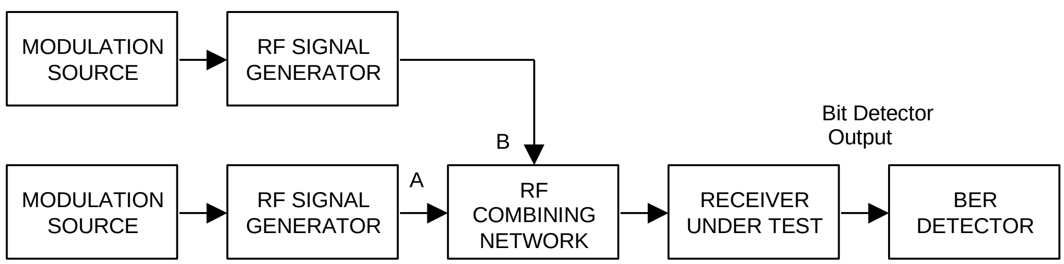
*digital simulcast adjacent channel rejection high* = $P_{\text{HIGH}} - P_{\text{REF}}$

*digital simulcast adjacent channel rejection low* = $P_{\text{LOW}} - P_{\text{REF}}$

The smaller of the above is the digital simulcast adjacent channel rejection.

2.1.7.3 Method of Measurement for Digital Offset Adjacent Channel Rejection




a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network, modulated with the standard tone test pattern. Reduce its level to obtain reference sensitivity. Record this level in dBm as $P_{\text{REF}}$.

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted C4FM input signal for 12.5 kHz channel spaced equipment, or a CQPSK input signal for 6.25 kHz channel spaced equipment, modulated with the standard interference test pattern to terminal B of the combining network. The modulation of this generator shall be uncorrelated to the modulation of the generator attached to terminal A.

e) Adjust the unwanted signal frequency to the adjacent channel frequency above and below the wanted signal frequency, with the frequency in each case offset toward the receiver frequency by 1 kHz for 12.5 kHz channel spaced equipment, or 500 Hz for 6.25 kHz spaced equipment. Adjust the unwanted signal level each time to reestablish the standard BER. Record these levels in dBm as $P_{\text{HIGH}}$ and $P_{\text{LOW}}$.

f) Calculate the digital offset adjacent channel rejection by the following:



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*digital offset adjacent channel rejection high* = $P_{\mathrm{HIGH}} - P_{\mathrm{REF}}$

*digital offset adjacent channel rejection low* = $P_{\mathrm{LOW}} - P_{\mathrm{REF}}$

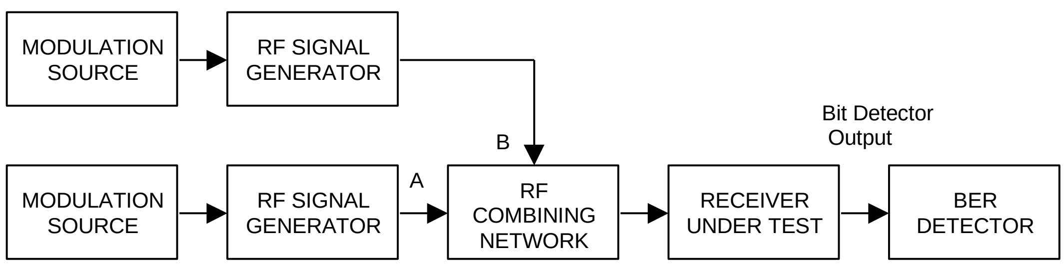
The smaller of the above is the digital offset adjacent channel rejection.

### 2.1.8 Co-Channel Rejection

2.1.8.1 Definition

The co-channel rejection is the ratio of the reference sensitivity to the level of an unwanted input signal. The unwanted signal has an amplitude that causes the BER produced by a wanted signal 3 dB in excess of the reference sensitivity to be reduced to the standard BER.

2.1.8.2 Method of Measurement




a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network, modulated with the standard tone test pattern. Reduce its level to obtain reference sensitivity. Record this level in dBm as $P_{\mathrm{REF}}$.

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted input signal modulated with the standard interference test pattern to terminal B of the combining network. The modulation of this generator shall be uncorrelated to the modulation of the generator attached to terminal A.



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e) Adjust the unwanted signal generator frequency to the receiver frequency and adjust its level to reestablish the standard BER. Record this level in dBm as $P_{\mathrm{CO}}$.

f) Calculate the co-channel rejection as follows:

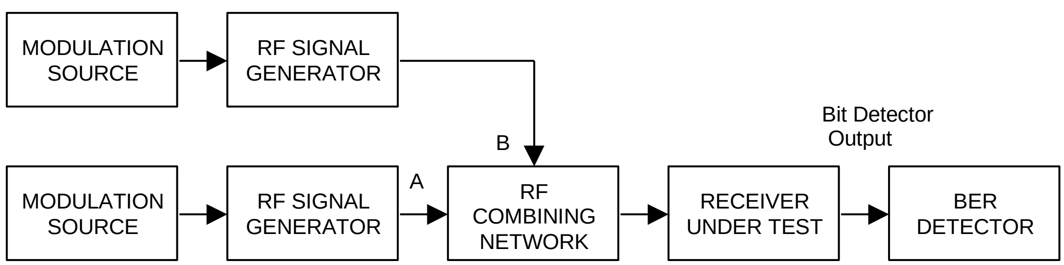
$$\textit{co-channel rejection} = P_{\mathrm{REF}} - P_{\mathrm{CO}}$$

### 2.1.9 Spurious Response Rejection

#### 2.1.9.1 Definition

The spurious response rejection is the ability of a receiver to prevent single unwanted signals from causing a degradation to the reception of a desired signal. It is expressed as the ratio of the level of a single unwanted input signal to the reference sensitivity. The unwanted signal has an amplitude that causes the BER produced by a wanted signal 3 dB in excess of the reference sensitivity to be degraded to the standard BER.

#### 2.1.9.1 Method of Measurement




a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network, modulated with the standard tone test pattern. Reduce its level to obtain reference sensitivity. Record this level in dBm as $P_{\mathrm{REF}}$ .

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted input signal to terminal B of the combining network. This generator shall be frequency modulated with a 400 Hz tone at 1500 Hz



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deviation. The level of this generator shall be adjusted according to the following:

$P_U = P_{REF} + SRR + 6$ dB

where:

$P_U$ is the level of the unwanted signal generator in dBm.

$P_{REF}$ is the level of reference sensitivity in dBm.

*SRR* is the manufacturer specified limit for spurious response rejection in dB.

e) Vary the unwanted signal frequency over a range from one half of the lowest IF frequency in the receiver to twice the receiver frequency or 1000 MHz, whichever is greater, to search for degradation of the BER. When a response is found, adjust the frequency of the unwanted signal to maximize the degradation. Exclude all responses within ±50 kHz of the receiver frequency.

f) At the frequency of each spurious response, change the level of the unwanted input signal until the standard BER is obtained. Record the frequency of the unwanted signal and record its level in dBm as $P_{SPUR}$ .

g) Calculate the spurious response rejection for each frequency concerned as follows:

*spurious response rejection* = $P_{SPUR} - P_{REF}$

### 2.1.10 Intermodulation Rejection

#### 2.1.10.1 Definition

The intermodulation rejection is the ability of a receiver to prevent two unwanted input signals, with a specific frequency relation to the wanted signal frequency, from causing degradation to the reception of a desired signal. It is expressed as the ratio of the level of two equal level unwanted signals to the reference sensitivity. The unwanted signals have an amplitude that causes the BER produced by the wanted signal 3 dB in excess of the reference sensitivity to be degraded to the standard BER.



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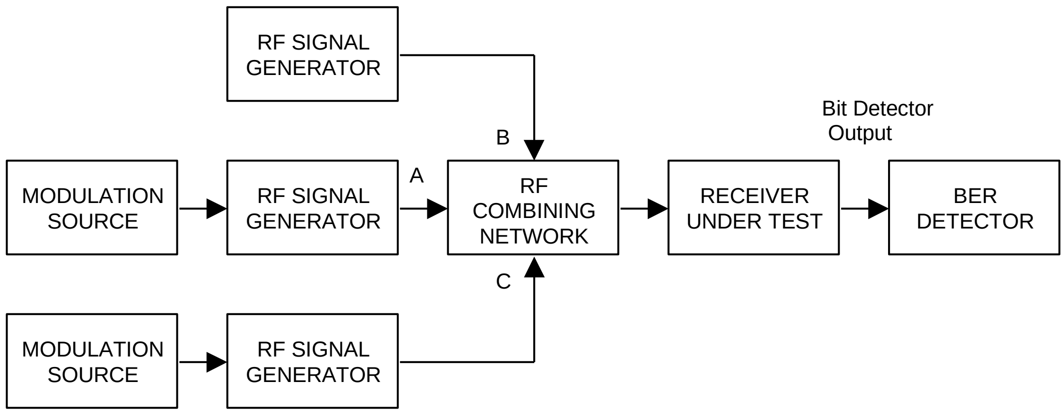
2.1.10.2 Method of Measurement




a) Connect the equipment as illustrated. Connect two additional signal generators (unwanted signal sources) to terminals B and C of an appropriate matching or combining network.

b) In the absence of the unwanted signals, apply the standard input signal at terminal A of the combining network, modulated with the standard tone test pattern. Reduce its level to obtain reference sensitivity. Record the level in dBm as $P_{\mathrm{REF}}$.

c) Increase the level of the wanted input signal by 3 dB.

d) Apply an unwanted, unmodulated input signal from the generator connected to terminal B. Adjust this generator frequency to the wanted frequency plus 50 kHz.

e) Apply an unwanted C4FM input signal for 12.5 kHz channel spaced equipment, or a CQPSK input signal for 6.25 kHz channel spaced equipment, modulated with the standard interference test pattern, from the generator connected to terminal C. Adjust this generator frequency to the wanted frequency plus 100 kHz. The modulation of this generator shall be uncorrelated to the modulation of the generator attached to terminal A.

f) Simultaneously increase the levels of the two unwanted signals.

g) Adjust the levels of the unwanted signals to be equal and to produce standard BER. Record this level in dBm as $P_{\mathrm{HIGH}}$.

h) Repeat the above steps adjusting the frequency of the signal generator



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connected to terminal B to the wanted frequency minus 50 kHz, and the frequency of the signal generator connected to terminal C to the wanted frequency minus 100 kHz. Record this level in dBm as $P_{LOW}$.

i) Calculate the intermodulation rejection as follows:

$$\textit{intermodulation rejection high} = P_{HIGH} - P_{REF}$$

$$\textit{intermodulation rejection low} = P_{LOW} - P_{REF}$$

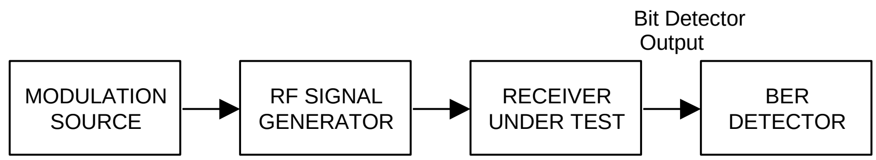
The smaller of the above is the intermodulation rejection.

### 2.1.11 Signal Displacement Bandwidth

2.1.11.1 Definition

The signal displacement bandwidth is the input signal frequency displacement that reduces the BER produced by a signal 6 dB in excess of the reference sensitivity, to the standard BER.

2.1.11.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal, with the standard tone test pattern, to the receiver input terminals.

c) Adjust the level of the input signal to achieve standard bit error rate (BER) when measured over at least a 250 ms time interval.

d) Increase the level of the signal generator by 6 dB.

e) Increase the input signal frequency until the standard BER is obtained. Record this frequency an $F_H$.

f) Decrease the input signal frequency until the standard BER is obtained. Record this frequency as $F_L$.



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g) Calculate the frequency differences by the following:

$F_{\mathrm{DIFF1}} = F_{\mathrm{H}} - \textit{nominal frequency}$

$F_{\mathrm{DIFF2}} = \textit{nominal frequency} - F_{\mathrm{L}}$

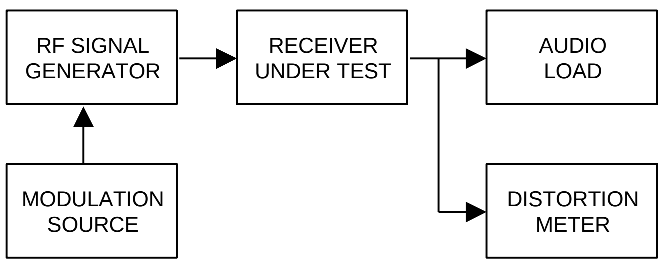
The smaller of $F_{\mathrm{DIFF1}}$ or $F_{\mathrm{DIFF2}}$ is the signal displacement bandwidth.

### 2.1.12 Audio Output Distortion

2.1.12.1 Definition

The audio output distortion is the voltage ratio, usually expressed as a percentage of the rms value of the undesired signal to the rms value of the complete signal, at the output of the receiver.

2.1.12.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal, with the standard tone test pattern, at the standard input signal level, to the receiver input terminals.

c) Adjust the receiver for rated audio frequency output power.

d) Measure the audio distortion factor at the audio frequency load.

e) Repeat step d) at an audio frequency output power level 17 dB below rated output power.

f) The values recorded in steps d) and e) are the audio output distortions for the respective audio power outputs.



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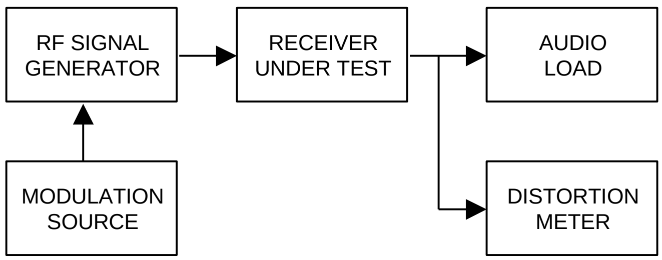
### 2.1.13 Residual Audio Noise Ratio

2.1.13.1 Definition

The residual audio noise ratio is the ratio of the rated output power to the audio output power that results during voice silence periods, and the audio output that results during the time when the receiver is muted compared to 1 mW.

2.1.13.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal, with the standard tone test pattern, at the standard input signal level, to the receiver input terminals.

c) Adjust the receiver for rated audio frequency output power, and record the audio output level as $V_{REF}$.

d) Change the input signal to the standard silence test pattern.

e) Measure the receiver audio output and record the level as $V_S$.

f) Remove the signal generator to mute the receiver and measure the receiver audio output. Record this level as $V_{MUTE}$.

g) Calculate the residual audio noise ratio as follows:

$$residual\ audio\ noise\ ratio\ (silence) = 20\ \log_{10}\left(\frac{V_{REF}}{V_S}\right)$$

$$residual\ audio\ noise\ power\ (mute) = 10\ \log_{10}\left(1000\frac{V^2{}_{MUTE}}{R_{LOAD}}\right)$$

where $V_{MUTE}$ is in Volts, and $R_{LOAD}$ is in Ohms.



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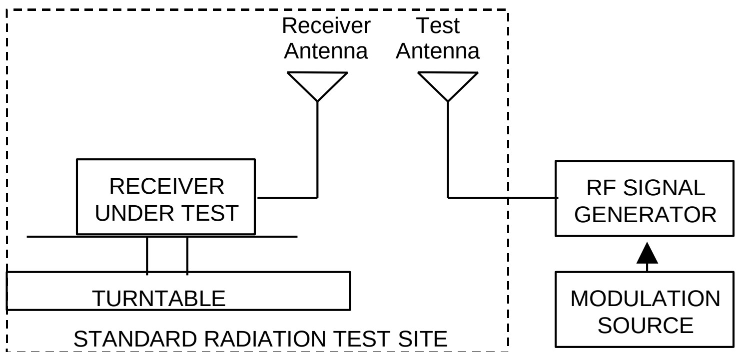
### 2.1.14 Average Radiation Sensitivity

2.1.14.1 Definition

The average radiation sensitivity of a receiver is the power received by a half-wave dipole measured into a 50 Ω load when substituted for a receiver that is receiving a signal at the reference sensitivity.

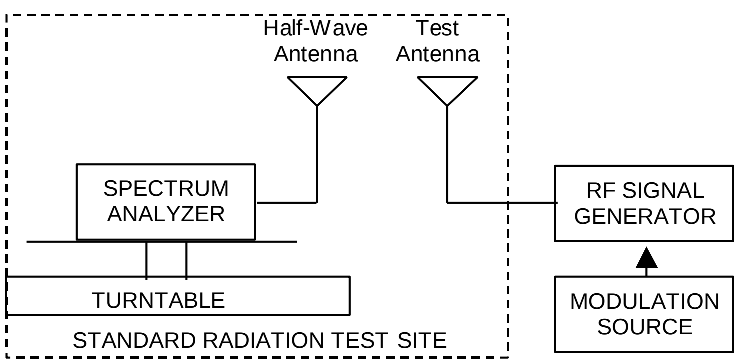
2.1.14.2 Method of Measurement




a) Place the receiver with its antenna to be tested on the turntable of the radiation test site.

b) Connect a signal generator modulated with the standard tone test pattern to a vertically polarized 1/2 wave length test antenna and fasten this antenna to the supporting mast.

c) Raise and lower the mast so that reference sensitivity is obtained in the receiver for the minimum signal generator level.




d) Replace the receiver under test with a half-wave vertically polarized



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antenna, connected to a spectrum analyzer. The center of the antenna should be in the same location as the receiver under test.

e) Record the power level measured by the spectrum analyzer in units of Watts.

f) Repeat steps c), d), and e) seven times, rotating the receiver under test 45 degrees each time.

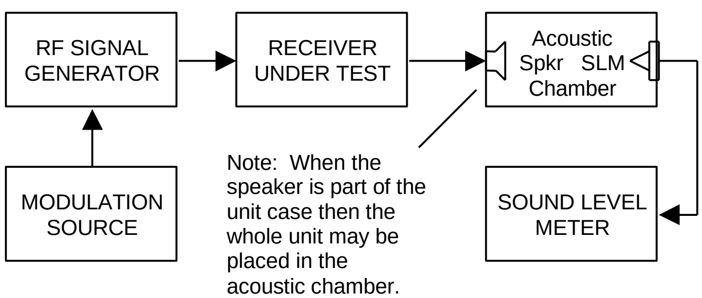
g) Average the eight measurements recorded in step e) in units of Watts. The average radiation sensitivity is the resulting average converted to dBm.

### 2.1.15 Acoustic Audio Output

2.1.15.1 Definition

The acoustic audio output is the level registered on a sound level meter at a distance of 50 cm from the front of the receiver acoustic transducer.

2.1.15.2 Method of Measurement




a) Mount the receiver in the acoustic chamber.

b) Apply a standard input signal, modulated with the standard tone test pattern, to the receiver antenna input terminals.

c) Operate the receiver at rated output power.

d) Place the microphone of a sound level meter 50 cm from the front surface of the receiver acoustic transducer.

e) Record the reading of the sound level meter.

f) The level recorded in step e) is the acoustic audio output.



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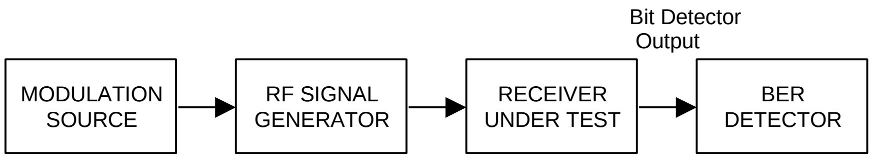
### 2.1.16 Bit Error Rate Floor

2.1.16.1 Definition

The bit error rate floor is the bit error rate that results when the input to the receiver is the standard input signal.

2.1.16.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Apply a standard input signal, with the standard tone test pattern, to the receiver input terminals.

c) Connect a bit error rate detector to the bit detector output of the receiver.

d) Measure the resulting bit error rate over at least a 10 second time interval. Record the bit error rate.

e) The bit error rate floor is the value obtained in step d).

### 2.1.17 Late Entry Unsquelch Delay

2.1.17.1 Definition

The late entry unsquelch delay is the time it takes for a receiver to detect the frame synchronization and network ID on a digital message and generate an audio output. The test is performed for late entry, which means that the synchronizing preamble (Header Data Unit) is absent from the message, and the receiver must detect frame synchronization during the middle of the message. This test applies to a transceiver in the conventional mode of operation.



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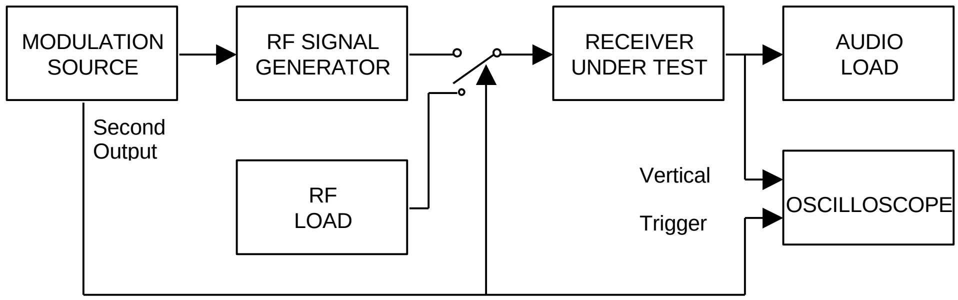
2.1.17.2 Method of Measurement




a) Connect the equipment as illustrated. The receiver under test shall be adjusted to receive the default net ID value of the modulation source. The receiver shall be set for a conventional channel with normal squelch operation.

b) With the RF signal generator connected to the receiver under test, adjust its level to obtain reference sensitivity.

c) Adjust the oscilloscope for a single sweep at a speed of 200 ms per division. The oscilloscope should trigger from the second output from the modulation source.

d) Repeat steps e), f), and g) enough times to collect 10 late entry unsquelch data samples with the modulation source generating a trigger on the start of Link Data Unit 1 (LDU1), and 10 samples with the modulation source generating a trigger on the start of Link Data Unit 2 (LDU2).

e) Clear the trigger so that it is not asserted. Before the trigger input is asserted, the modulation source should be inactive, the switch should connect the load to the receiver under test, and the oscilloscope should have its trigger armed.

f) Activate the modulation source. The trigger input should originate from the modulation source either at the start of Link Data Unit 1 (LDU1), or at the start of Link Data Unit 2 (LDU2). The switch should gate the RF signal generator output to the receiver under test, and simultaneously trigger the oscilloscope.

g) Measure the time it takes for a test tone to appear on the oscilloscope. Record this value. If the tone does not appear within one sweep time, repeat steps e), f), and g) until 20 samples are successfully recorded. Record the number of times that the tone did not appear within the sweep time of the



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oscilloscope.

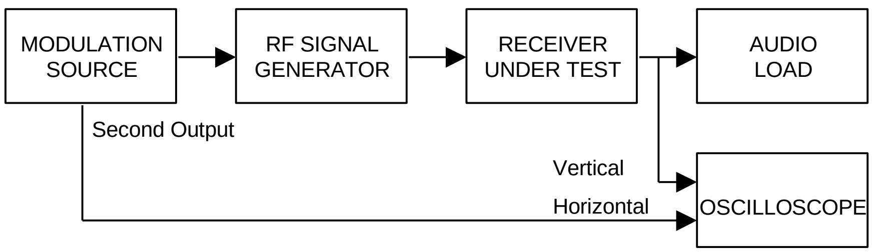
h) The late entry unsquelch delay is the average of the 20 samples recorded in step g).

### 2.1.18 Receiver Throughput Delay

2.1.18.1 Definition

Receiver throughput delay is the time it takes for a receiver to produce an audio output following the introduction of a tone test pattern.

2.1.18.2 Method of Measurement




a) Connect the equipment as illustrated.

b) With the RF signal generator connected to the receiver under test, adjust its level to obtain the standard input signal level.

c) Adjust the oscilloscope for a single sweep at a speed of 200 ms per division. The oscilloscope should trigger from the second output from the modulation source.

d) Repeat steps e), f), and g) enough times to collect 10 data samples.

e) The modulation source should be set to produce the standard silence test pattern. The second output should be set to produce the no trigger pattern. Arm the oscilloscope trigger.

f) Change the modulation source to produce the standard tone test pattern simultaneous with the second output providing the trigger on the start of Link Data Unit 1 (LDU1). (The switch from silence to tone test patterns occurs at the end of LDU2, and the beginning of LDU1).

g) Measure the time it takes from the trigger input until a test tone appears on



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the oscilloscope. Record this value.

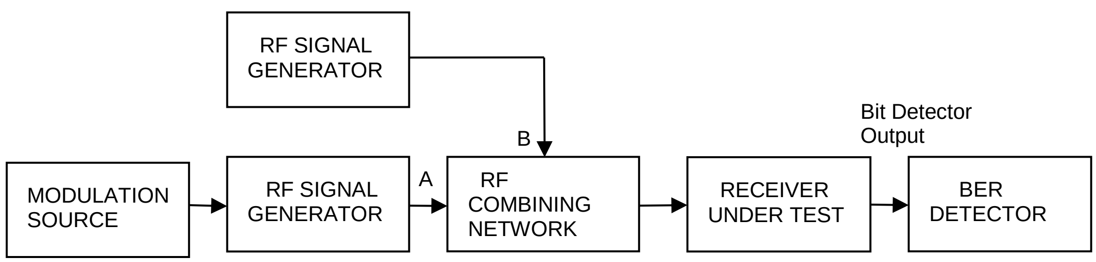
h) The receiver throughput delay is the average of the 10 samples recorded in step g).

## 2.1.19 Blocking Rejection

### 2.1.19.1 Definition

The blocking rejection is the ratio of the level of an unwanted input signal to the reference sensitivity. The unwanted signal is of an amplitude that causes the BER produced by a wanted signal 3 dB in excess of the reference sensitivity to be reduced to the standard BER.

### 2.1.19.2 Method of Measurement




a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level as $P_{REF}$ .

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted input signal, unmodulated, to terminal B of the combining network.

e) Adjust the unwanted signal frequency to 1 MHz, 2 MHz, 5 MHz, and 10 MHz above and below the wanted signal frequency and adjust its level each time to reestablish the standard BER. Record in dBm the lowest of the



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readings obtained for frequencies above the desired frequency as $P_{HIGH}$. Record in dBm the lowest of the readings obtained for frequencies below the desired frequency as $P_{LOW}$ .

Note: In the event that a known spurious response falls on any of the above test frequencies, it is acceptable to slightly adjust the test frequency lower or higher to eliminate the effect of the spurious response.

f) Calculate the blocking rejection by the following:

$$\textit{blocking rejection high} = P_{HIGH} - P_{REF}$$

$$\textit{blocking rejection low} = P_{LOW} - P_{REF}$$

The smaller of the above is the blocking rejection.



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## 2.2 Methods of Measurement for Transmitters

This section details test definitions and methods of measurement of the characteristics of digital private land mobile transmitters in vehicular (mobiles), fixed (base stations), or handheld (portable) installations employing C4FM, CQPSK, or a linear simulcast modulation, with or without a vocoder, with or without encryption.

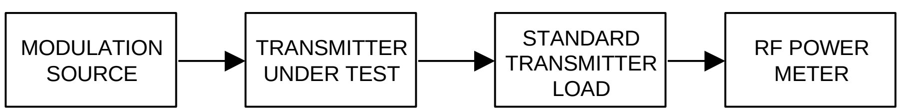
When the transmitter is equipped with one or more special function subsystems, the subsystems must be disabled. This section (2.2) does not cover testing of transmitters that include subsystems that cannot be disabled or bypassed.

### 2.2.1 RF Output Power

2.2.1.1 Definition

The RF output power of a transmitter for this service is the power available at the output terminals of the transmitter when the output terminals are connected to the standard transmitter load.

2.2.1.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter test pattern.

c) Measure the transmitter output power during the defined duty cycle (see 1.4.2). Correct for all losses in the RF path.

d) The value measured in step c) is the RF output power.

### 2.2.2 Operating Frequency Accuracy

2.2.2.1 Definition

The operating frequency accuracy is the ability of the transmitter to operate on its assigned frequency.



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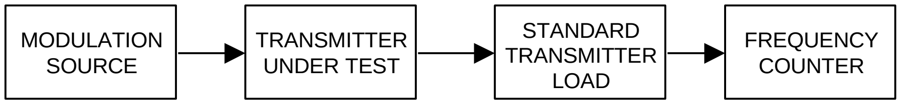
2.2.2.2 Method of Measurement (AFC disabled)




a) Connect the equipment as illustrated.

b) Operate the equipment in standby conditions for 15 minutes before proceeding.

c) Modulate the transmitter with the standard transmitter low deviation pattern.

d) Record the frequency of the transmitter as $MOF_{MHz}$ .

e) Calculate the ppm frequency error by the following:

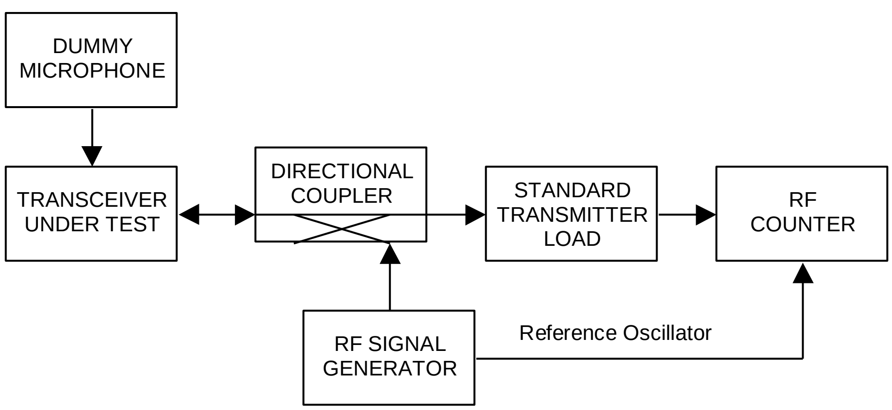
$$ppm\ error = \left( \frac{MOF_{MHz}}{AF_{MHz}} - 1 \right) * 10^6$$

where

$MOF_{MHz}$ is the measured operating frequency in MHz
$AF_{MHz}$ is the assigned frequency in MHz

f) The value calculated in step e) is the operating frequency accuracy.

2.2.2.3 Method of Measurement (For Transmitters with AFC Locked to the Base Station)




a) Connect the equipment as illustrated.



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b) Operate the equipment in standby conditions for 15 minutes before proceeding.

c) Transmit a signal from the RF digitally modulated signal generator with the automatic frequency control test pattern to simulate a base station.

d) Set the transceiver under test to receive the signal from the RF digitally modulated signal generator and lock the automatic frequency control (AFC).

e) Set the transceiver to transmit with the standard test pattern.

f) Record the frequency of the transmitter as $MOF_{\mathrm{MHz}}$ .

g) Calculate the ppm frequency error by the following:

$$ppm\ error = \left( \frac{MOF_{MHz}}{AF_{MHz}} - 1 \right) * 10^{6}$$

where

$MF_{\mathrm{MHz}}$ is the Measured Operating Frequency in MHz
$AF_{\mathrm{MHz}}$ is the Assigned Frequency in MHz

h) The value recorded in step g) is the operating frequency accuracy.

### 2.2.3 Electrical Audio Performance

2.2.3.1 Definition

The electrical audio performance is the degree of closeness to which the audio path of the transmitter follows a prescribed characteristic.



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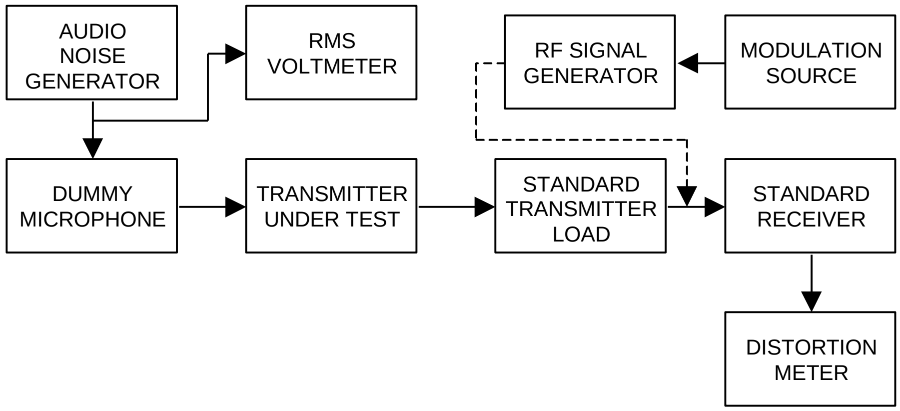
2.2.3.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Connect the signal generator to the standard receiver. Modulate the signal generator with the standard tone test pattern.

c) Measure the output of the standard receiver. Record the rms level as $V_{REF}$.

d) Connect the transmitter output through the standard transmitter load to the standard receiver.

e) Modulate the transmitter with the standard transmitter audio modulation input.

f) Adjust the level of the audio noise generator until the output of the standard receiver equals $V_{REF.}$

g) Record the rms level of the audio noise generator.

h) The audio generator level recorded in step g) is the electrical audio performance.

## 2.2.4 Acoustic Audio Performance

2.2.4.1 Definition

The acoustic audio performance is the degree of closeness to which the acoustic input to the transmitter follows a prescribed characteristic.



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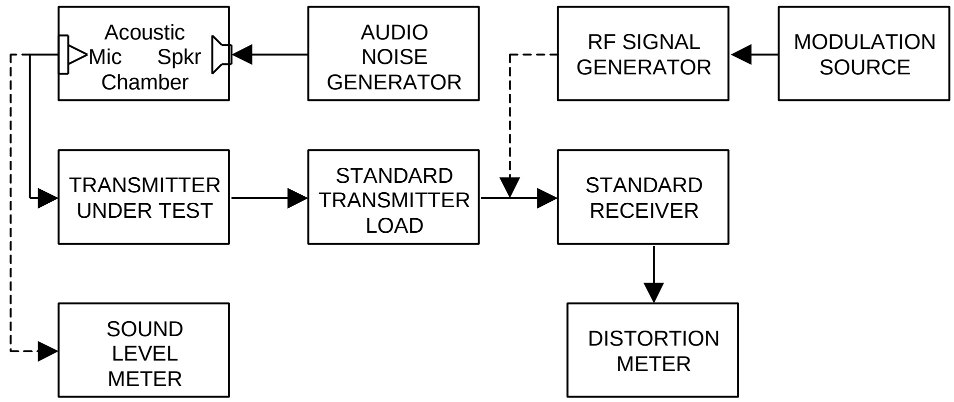
2.2.4.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Connect the signal generator to the standard receiver. Modulate the signal generator with the standard tone test pattern.

c) Measure the output of the standard receiver. Record the level as $V_{REF}$.

d) Connect the transmitter output through the standard transmitter load to the standard receiver.

e) Place the transceiver microphone 5 cm away from the acoustic transducer (loud speaker) that has a free opening of less than 4 square cm.

f) Set the audio noise generator to generate band limited pink noise. Adjust the level of the audio noise generator until the output of the standard receiver equals $V_{REF}$.

g) Replace the transceiver microphone with a sound level meter 5 cm away from the acoustic transducer. Set the sound level meter to use C weighting. Record the level with the sound level meter.

h) The level recorded in step g) is the acoustic audio performance.



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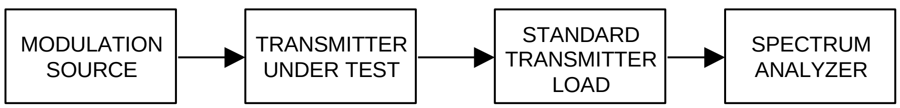
### 2.2.5 Modulation Emission Spectrum

2.2.5.1 Definition

The term modulation emission spectrum denotes the sideband energy produced at a frequency separation from the assigned frequency within the test bandwidth due to modulation and all sources of unwanted noise within the transmitter.

2.2.5.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter test pattern.

c) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 30 kHz.
2) Video Bandwidth = 30 kHz.
3) Sweep Speed ≤2000 Hz/second.
4) Detector Mode = Positive peak with peak hold.
5) Span that will allow proper viewing of the test bandwidth.

d) Set the center frequency of the spectrum analyzer to the assigned transmitter frequency. Key the transmitter, and set the peak level of the modulated signal to a full scale reference line. This is the 0 dB reference for the attenuation measurement.

e) Adjust the spectrum analyzer for the following settings:

For NTIA frequencies in the range of 138 MHz to 174 MHz and 380 MHz to 420 MHz:
1) Resolution Bandwidth = 300 Hz
2) Video Bandwidth = 3000 Hz.
3) Sweep Speed ≤ 2000 Hz/second.
4) Detector Mode = Positive peak with peak hold.
5) Span that will allow proper viewing of the test bandwidth.

For all FCC frequency ranges:



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1) Resolution Bandwidth = 100 Hz
2) Video Bandwidth = 1000 Hz.
3) Sweep Speed = 2000 Hz/second.
4) Detector Mode = Positive peak with peak hold.
5) Span that will allow proper viewing of the test bandwidth.

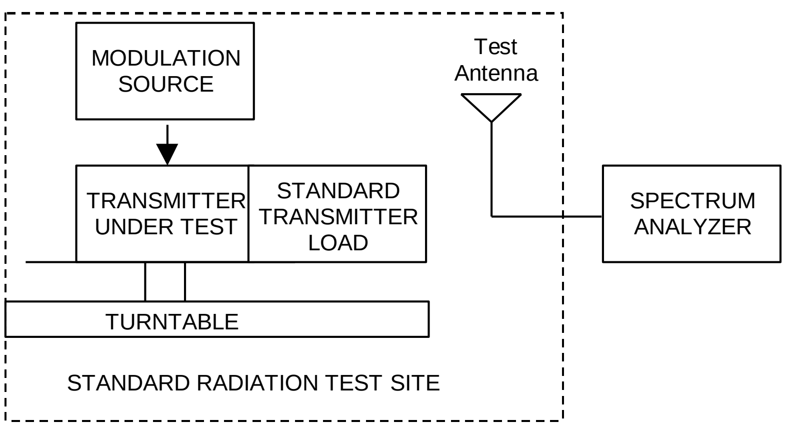
f) Record the resulting spectrum analyzer presentation of the emission spectrum with an on-line recording device or in a photograph. The emission limit mask shall be included as a trace on the analyzer display or drawn on the plotted graph or photograph. The spectrum analyzer presentation is the modulation emission spectrum.

### 2.2.6 Unwanted Emissions: Radiated Spurious

2.2.6.1 Definition

Radiated spurious emissions are emissions from the equipment when transmitting into a non-radiating load on a frequency or frequencies that are outside an occupied band sufficient to ensure transmission of information of required quality for the class of communications desired.

2.2.6.2 Method of Measurement




a) Connect the equipment as illustrated above.

b) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
2) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.



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3) Sweep Speed slow enough to maintain measurement calibration
4) Detector Mode = Positive Peak.

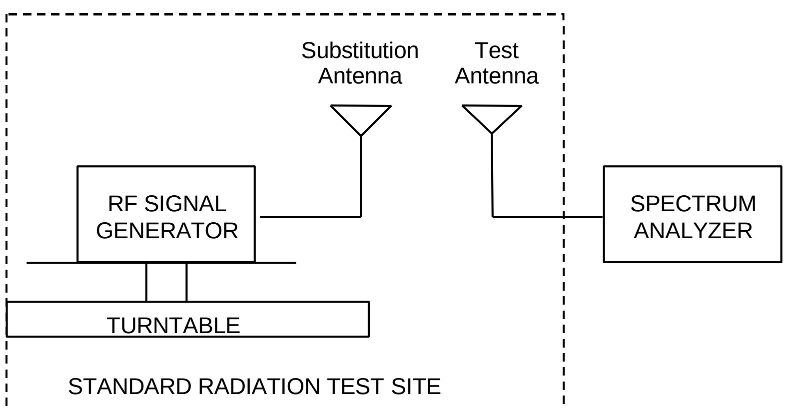
c) Place the transmitter to be tested on the turntable in the standard test site. The transmitter is transmitting into a nonradiating load that is placed on the turntable. The RF cable to this load should be of minimum length.

d) For each spurious measurement the test antenna should be adjusted to the correct length for the frequency involved. This length may be determined from a calibration ruler supplied with the equipment. Measurements shall be made from the lowest radio frequency generated in the equipment to the tenth harmonic of the assigned frequency, except for the region close to the assigned frequency equal to ± the test bandwidth.

e) Key the transmitter with the vocoder operating, if it exists. Otherwise, modulate the transmitter with the standard transmitter test pattern.

f) For each spurious frequency, raise and lower the test antenna from 1 m to 4 m to obtain a maximum reading on the spectrum analyzer with the test antenna at horizontal polarity. Then the turntable should be rotated 360° to determine the maximum reading. Repeat this procedure to obtain the highest possible reading. Record this maximum reading.

g) Repeat step f) for each spurious frequency with the test antenna polarized vertically.




h) Reconnect the equipment as illustrated above.

i) Keep the spectrum analyzer adjusted as in step b).

j) Dekey the transmitter, remove it and its load, and replace them with a substitution antenna (the antenna should be half-wavelength for each



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frequency involved). The center of the substitution antenna should be approximately at the same location as the center of the transmitter. At the lower frequencies, where the substitution antenna is very long, this will be impossible to achieve when the antenna is polarized vertically. In such case the lower end of the antenna should be 0.3 m above the ground.

k) Feed the substitution antenna at the transmitter end with a signal generator connected to the antenna by means of a non-radiating cable. With the antennas at both ends horizontally polarized and with the signal generator tuned to a particular spurious frequency, raise and lower the test antenna to obtain a maximum reading at the spectrum analyzer. Adjust the level of the signal generator output until the previously recorded maximum reading for this set of conditions is obtained. This should be done carefully repeating the adjustment of the test antenna and generator output.

l) Repeat step k) with both antennas vertically polarized for each spurious frequency.

m) Calculate power in dBm into a reference ideal half-wave dipole antenna by reducing the readings obtained in steps k) and l) by the power loss in the cable between the generator and the antenna and further corrected for the gain of the substitution antenna used relative to an ideal half-wave dipole antenna by using the following formula:

$$P_d(dBm) = P_g(dBm) - \textit{cable loss (in dB)} + \textit{antenna gain (in dB)}$$

where:

$P_d$ is the dipole equivalent power and

$P_g$ is the generator output power into the substitution antenna.

n) The $P_d$ levels record in step m) are the absolute levels of radiated spurious emissions in dBm. The radiated spurious emissions in dB can be calculated by the following:

*radiated spurious emissions (dB) =*

$$10\log_{10}\left(\frac{TX\ \ power\ \ in\ Watts}{0.001}\right) - the\ P_d\ \ levels\ \ in\ \ step\ \ m)$$

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.



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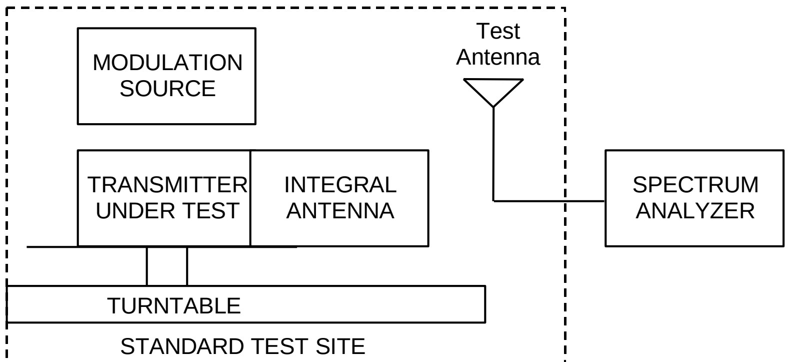
2.2.6.3 Method of Measurement (EIRP in GNSS Band:1.559 to 1.610 GHz)

This test is specifically applicable to transmitter equipment designed for the 700 MHz frequency band. It is recommended that all land mobile equipment be characterized per this method and conform to the associated standard limit value. This test is only applicable to equipment using an integral antenna. See 2.2.6.4 for methods applicable to equipment that utilizes an external antenna.




a) Connect the equipment as illustrated.

b) Adjust the spectrum analyzer for the following settings:

   1) Resolution Bandwidth = 1 MHz.
   2) Video Bandwidth ≥ 3 times the resolution bandwidth.
   3) Sweep Speed slow enough to maintain measurement calibration.
   4) Detector Mode = mean or average.

c) Place the transmitter to be tested on the turntable in the standard test site, or an FCC listed site compliant with ANSI C63.4-2001 clause 5.4.

d) For each spurious measurement the test antenna should be adjusted to the correct length for the frequency involved. This length may be determined from a calibration ruler supplied with the equipment. Measurements shall be made from 1.559 GHz to 1.610 GHz.

e) Key the transmitter. Modulate the transmitter with the standard transmitter test pattern.

f) For each spurious frequency, raise and lower the test antenna from 1 m to 4 m to obtain a maximum reading on the spectrum analyzer with the test antenna at horizontal polarity. Then the turntable should be rotated 360° to



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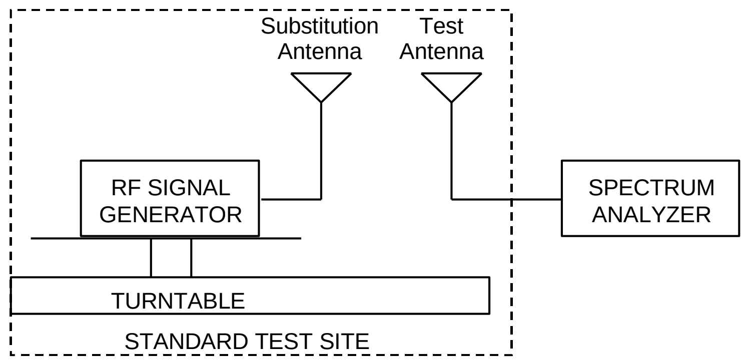
determine the maximum reading. Repeat this procedure to obtain the highest possible reading. Record this maximum reading.

g) Repeat step f) for each spurious frequency with the test antenna polarized vertically.




h) Reconnect the equipment as illustrated.

i) Keep the spectrum analyzer adjusted as in step b).

j) Remove the transmitter and replace it with a substitution antenna (the antenna should be half-wavelength for each frequency involved). The center of the substitution antenna should be approximately at the same location as the center of the transmitter.

k) Feed the substitution antenna at the transmitter end with a signal generator connected to the antenna by means of a nonradiating cable. With the antennas at both ends horizontally polarized, and with the signal generator tuned to a particular spurious frequency, raise and lower the test antenna to obtain a maximum reading at the spectrum analyzer. Adjust the level of the signal generator output until the previously recorded maximum reading for this set of conditions is obtained. This should be done carefully repeating the adjustment of the test antenna and generator output.

l) Repeat step k) with both antennas vertically polarized for each spurious frequency.

m) Calculate the equivalent isotropic radiated power (EIRP), in dBm, by reducing the readings obtained in steps k) and l) by the power loss in the cable between the generator and antenna, corrected for the gain of the substitution antenna used relative to an ideal half-wave dipole antenna, and then correct to an isotropic radiator.



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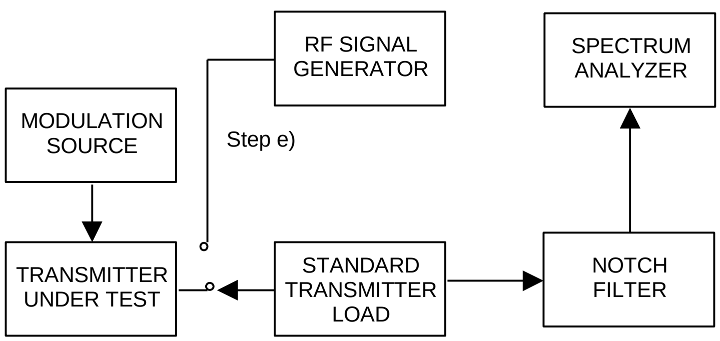
n) The levels record in step m) are the absolute levels of the wideband radiated spurious emissions, EIRP, in dBm.

o) For the narrowband spurious, repeat steps c) through n) using the following spectrum analyzer settings:

1) Resolution Bandwidth = 1 kHz.
2) Video Bandwidth = 3 kHz
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = mean or average.

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.

2.2.6.4 Method of Measurement (Calculated EIRP in the GNSS Band: 1.559 to 1.610 GHz)




a) Connect the equipment as illustrated. Modulate the transmitter with the standard transmitter test pattern.

b) Use the spectrum analyzer settings prescribed in 2.2.6.3 b) and o) for the wideband and narrowband cases respectively.

c) Adjust the center frequency of the spectrum analyzer for incremental coverage of the GNSS frequency band.

d) Record the frequencies and levels of the spurious emissions for the wideband and narrowband configurations.



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e) Replace the transmitter under test with the signal generator and adjust the signal level to reproduce the frequencies and levels of every spurious emission recorded in step d). Record the signal generator levels in dBm.

f) Calculate the equivalent isotropic radiated power (EIRP), in dBm, by correcting the measured levels by the loss of elements feeding the antenna and the isotropic gain of the antenna as follows:

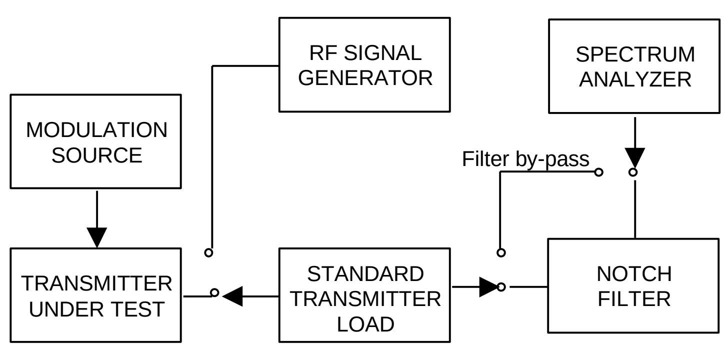
*EIRP* (dBm) = *Level* (dBm) – *Loss* (dB) + *Antenna Gain* (dBi)

### 2.2.7 Unwanted Emissions: Conducted Spurious

2.2.7.1 Definition

Conducted spurious emissions are emissions at the antenna terminals on a frequency or frequencies that are outside a band sufficient to ensure transmission of information of required quality for the class of communication desired.

2.2.7.2 Method of Measurement




a) Connect the equipment as illustrated, with the notch filter by-passed. Modulate the transmitter with the standard transmitter test pattern.

b) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 30 kHz.
2) Video Bandwidth = 30 kHz.
3) Sweep Speed ≤2000 Hz/second.



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4) Detector Mode = Positive peak.
5) Span that will allow proper viewing of the test bandwidth.

c) Set the center frequency of the spectrum analyzer to the assigned transmitter frequency, key the transmitter, and set the level of the transmitter signal to the full scale reference line.

d) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
2) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = Positive Peak.

e) Adjust the center frequency of the spectrum analyzer for incremental coverage of the range from:

1) The lowest radio frequency generated in the equipment to the assigned frequency minus the test bandwidth.

2) The assigned frequency plus the test bandwidth to a frequency up to, but not including, 2 times the assigned frequency.

f) Record the frequencies and levels of spurious emissions from step e).

g) De-key the transmitter and insert the notch filter between it and the spectrum analyzer.

h) Re-key the transmitter. Set the center frequency of the spectrum analyzer to the assigned frequency of the transmitter. Set the level of the transmitter signal to the full scale reference line

i) Adjust the spectrum analyzer for the widest span and narrowest resolution bandwidth that will result in a noise floor 10 dB less than the lowest spurious to be measured.

j) Adjust the center frequency of the spectrum analyzer for incremental coverage of the range from a frequency equal to 2 times the assigned frequency and to the tenth harmonic of the carrier frequency.



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k) Record the frequencies and levels of spurious emissions from step j).

l) Replace the transmitter under test with the signal generator and adjust the signal level to reproduce the frequencies and levels of every spurious emission recorded in step f), with the notch filter by-passed, and the frequencies and levels of every spurious emission recorded in step k), with the notch filter inserted. Record the signal generator levels in dBm.

m) The levels recorded in step l) are the absolute levels of conducted spurious emissions in dBm. The conducted spurious attenuation can be calculated by the following:

*conducted spurious attenuation (dB) =*

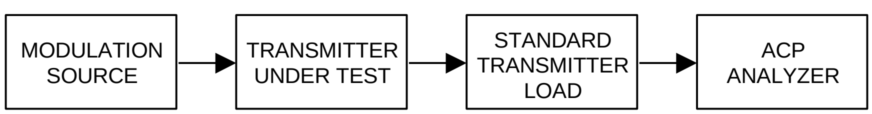
$$10 \log_{10}\left(\frac{TX\ \ power\ in\ Watts}{0.001}\right) - the\ levels\ in\ step\ l)$$

## 2.2.8 Unwanted Emissions: Adjacent Channel Power Ratio

### 2.2.8.1 Definition

The adjacent channel power ratio is the ratio of the total power of a transmitter, under prescribed conditions and modulation, within its maximum authorized bandwidth to that part of the output power that falls within a prescribed bandwidth centered on the nominal frequency of either of the adjacent channels or channels further offset above or below the assigned carrier frequency.

### 2.2.8.2 Method of Measurement




a) Connect the equipment as illustrated. The transmitter is set to produce the power determined in 2.2.1 at the assigned frequency. The adjacent channel power analyzer is set to use average power detection (sample or rms detector) and a span of 100 kHz.

b) The measurement bandwidth settings and markers of the analyzer shall be centered at the transmitter operating frequency, and at the upper and lower adjacent channel frequencies using a power measurement bandwidth and resolution bandwidth as specified in the Digital C4FM/CQPSK Transceiver Performance Recommendations document, **[R2]**. The video bandwidth



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shall be set to at least ten times the resolution bandwidth.

c) Modulate the transmitter with the standard transmitter test pattern.

d) The power shall be measured on the adjacent channel power analyzer in a passband whose 6 dB bandwidth is the transmitter authorized bandwidth, and shall be recorded in dBm as $P_{REF}$.

e) The power shall be measured on the adjacent channel power analyzer in the specified measurement bandwidth centered at both the upper and lower specified frequency offsets from the carrier frequency, as given in **[R2]** clause 3.2.8. Each lower frequency value shall be recorded in dBm as $P_{ADJL}$, and each upper frequency value shall be recorded in dBm as $P_{ADJU}$.

f) For each frequency offset specified in **[R2]** clause 3.2.8, calculate each lower adjacent channel power ratio, $ACPR_L$, as follows:

$$ACPR_L = P_{REF} - P_{ADJL}.$$

g) For each frequency offset specified in **[R2]** clause 3.2.8, calculate each upper adjacent channel power ratio, $ACPR_U$, as follows:

$$ACPR_U = P_{REF} - P_{ADJU}.$$

h) For each specified frequency offset the adjacent channel power ratio is the lesser of $ACPR_L$ or $ACPR_U$.

Note: To accurately measure ACPR values greater than 70 dB, it may be necessary to increase the dynamic range of the measuring system. Measurement system dynamic range extension can be realized by utilizing selectivity to pass the frequency band of interest or attenuate the transmitter output signal. For the swept portion of the test, methods similar to those given in 2.2.6 using the noted resolution bandwidth and detector type are suggested.

### 2.2.9 Intermodulation Attenuation

#### 2.2.9.1 Definition

Intermodulation attenuation is the capability of a transmitter to avoid the generation of signals in the nonlinear elements caused by the presence of the transmitter output and an interfering signal entering the transmitter via the antenna. It is specified as the ratio, in dB, of the power level of the third order intermodulation product to the RF output power level.



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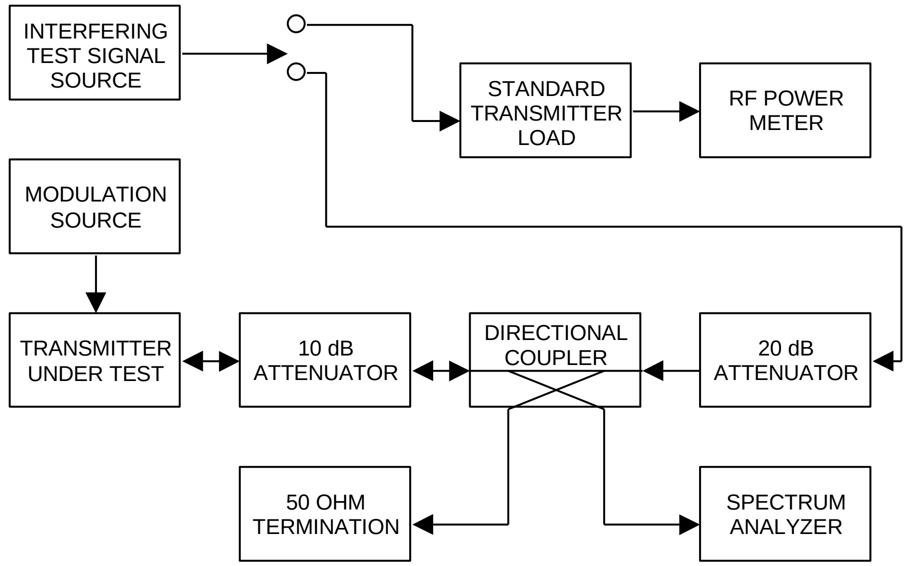
2.2.9.2 Method of Measurement




a) Connect the equipment as illustrated, with the interfering test signal source connected to the standard transmitter test load. In order to reduce the influence of mismatch errors it is important that the 10 dB power attenuator is coupled to the transmitter under test with the shortest possible connection. The interfering test signal source is an unmodulated RF carrier providing the same power output as the transmitter under test. The transmitter under test and the interfering test signal source shall be physically separated in such a way that the measurement is not influenced by direct radiation.

b) Adjust the spectrum analyzer to give a maximum indication. Set its frequency scan width to 500 kHz.

c) Set the frequency of the interfering test signal source to within 50 kHz to 100 kHz above the frequency of the transmitter under test. The frequency shall be chosen in such a way that the intermodulation components to be measured do not coincide with other spurious components.

d) Adjust the power output of the interfering test signal source to equal the RF output power level of the transmitter under test. This is the power level that was measured in 2.2.1.

e) Switch the interfering signal source from the standard load to the 20 dB attenuator. Modulate the transmitter with the standard transmitter low deviation pattern. Key the transmitter. Record the largest third order



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intermodulation component from the spectrum analyzer in dBm as $I_{LVL}$ .

f) Record the transmitter under test RF output power level from the spectrum analyzer in dBm as $S_{LVL}$ .

g) Calculate the intermodulation ratio as:

Intermodulation ratio = $S_{LVL} - I_{LVL}$

h) Set the frequency of the interfering test signal source to within 50 kHz to 100 kHz below the frequency of the transmitter under test. The frequency shall be chosen in such a way that the intermodulation components to be measured do not coincide with other spurious components.

i) Repeat steps d) through g).

j) The lower of the two readings obtained in steps g) and i) is the intermodulation attenuation.

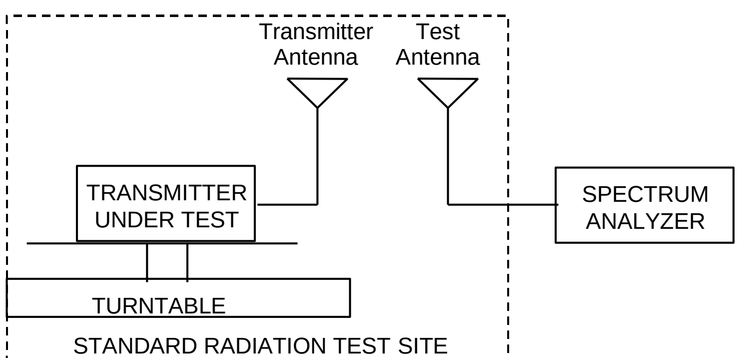
## 2.2.10 Radiated Power Output

### 2.2.10.1 Average Radiated Power Output

#### 2.2.10.1.1 Definition

The average radiated power of a licensed device is the equivalent power required, when delivered to a half-wave dipole antenna, to produce at a distant point the same average received power as produced by the licensed device.

#### 2.2.10.1.2 Method of Measurement




a) Connect the equipment as illustrated. Place the transmitter to be tested on



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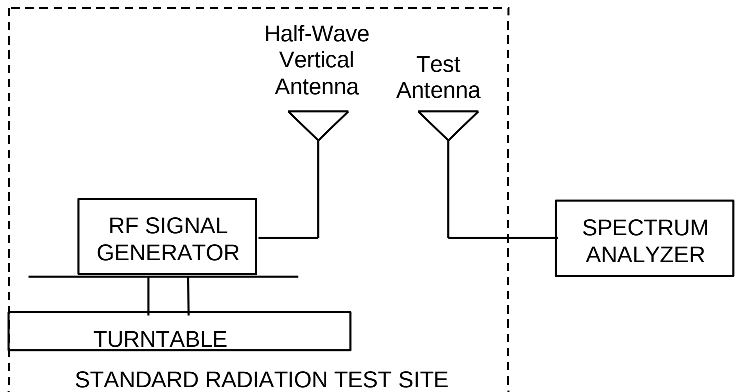
the turntable in the standard test site. Both antennas shall be vertically polarized.

b) Raise and lower the test antenna from 1 m to 6 m with the transmitter facing the antenna and record the highest received signal in dBm as $LVL_i$ .

c) Repeat step b) for seven additional readings at 45$^{o}$ interval positions of the turn table.




d) Replace the transmitter under test with a half-wave vertically polarized antenna. The center of the antenna should be at the same location as the transmitter under test. Connect the antenna to a signal generator with a known output power and record the path loss in dB as *LOSS*.

e) Calculate the average radiated output power from the readings in step c) and d) by the following:

$$average\ radiated\ \ power = 10\log_{10}\left(1/8\sum 10^{\frac{LVL_1 + Loss}{10}}\right) \qquad \text{dBm}$$

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.

2.2.10.2 Effective Radiated Power (ERP)

2.2.10.2.1 Definition and Application

The Effective Radiated Power is defined as the product of the power applied to an antenna and its gain relative to an ideal half wave dipole in a given direction. Maximum ERP is the maximum ERP in any direction.

For equipment using an antenna with known radiation characteristics ERP is a



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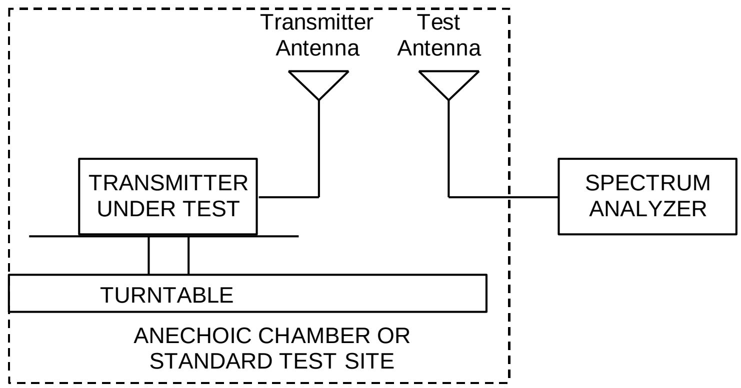
characteristic that can be calculated as well as measured,

(Note: Effective Isotropic Radiated Power (EIRP) can be computed using the following:

$EIRP$ (dBm ) = $ERP$ (dBm) + 2.15 (dB)

2.2.10.2.2 Method of Measurement




a) Connect the equipment as illustrated. Mount the equipment with the manufacturer specified antenna in a vertical orientation on a manufacturer specified mounting surface located on a non-conducting rotating platform of a RF anechoic chamber (preferred) or a standard radiation site.

b) Key the transmitter, then rotate the EUT 360$^{o}$ azimuthally and record spectrum analyzer power level (LVL) measurements at angular increments that are sufficiently small to permit resolution of all peaks. If a standard radiation test site is used, raise and lower the test antenna to obtain a maximum reading at each angular increment. (Note: several batteries may be needed to offset the effect of battery voltage droop, which should not exceed 5% of the manufactured specified battery voltage during transmission).



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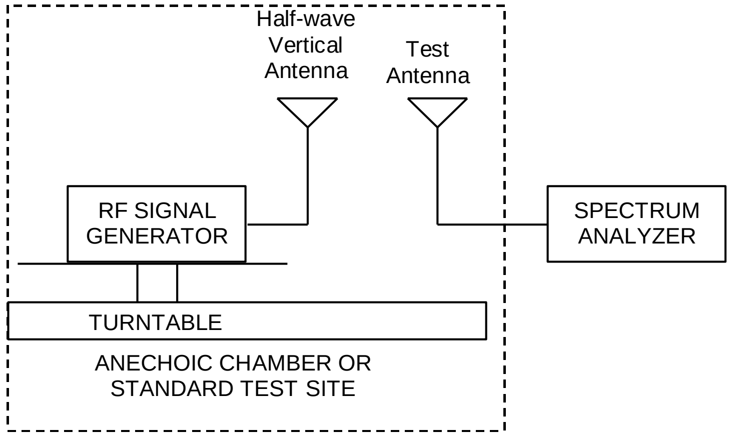


c) Replace the transmitter under test with a vertically polarized half-wave dipole (or an antenna whose gain is known relative to an ideal half-wave dipole). The center of the antenna should be at the same location as the center of the antenna under test.

d) Connect the antenna to a signal generator with a known output power and record the path loss (in dB) as *LOSS*. If a standard radiation test site is used, raise and lower the test antenna to obtain a maximum reading.

*LOSS* = *Generator Output Power* (dBm) – *Analyzer reading* (dBm)

e) Determine the effective radiated output power at each angular position from the readings in steps b) and d) using the following equation:

*ERP* (dBm) = *LVL* (dBm) + *LOSS* (dB)

f) The maximum ERP is the maximum value determined in the preceding step.

2.2.10.2.3 Method of Calculation

When calculating ERP, in addition to knowing the antenna radiation and matching characteristics, it is necessary to know the loss values of all elements (e.g. transmission line attenuation, mismatches, filters, combiners) interposed between the point where transmitter output power is measured, and the point where power is applied to the antenna. ERP can then be calculated as follows:



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*ERP* (dBm) = *Output Power* (dBm) - *Losses* (dB) + *Antenna Gain* (dBd)

where:

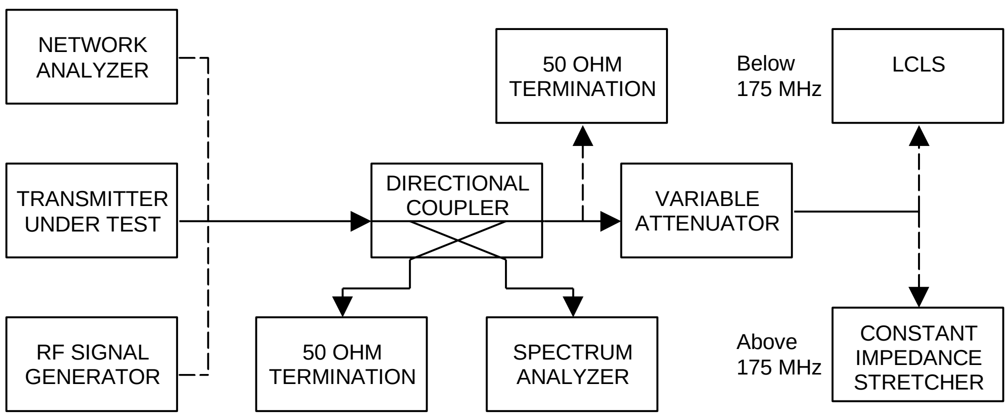
dBd refers to gain relative to an ideal dipole.

### 2.2.11 Conducted Spurious Emission into VSWR

2.2.11.1 Definition

Conducted Spurious Emissions into VSWR is the ability of a transmitter to not produce any conducted spurious signals greater than allowed for the conducted spurious emissions when operated in a load different from the standard load.

2.2.11.2 Method of Measurement




a) Connect the equipment as illustrated.

b) For frequencies up to 175 MHz, recommend using a lumped constant line stretcher (LCLS) as the variable load (see1.5.23 and 1.5.24 for the typical values of the inductors and capacitors).

c) For frequencies above 175 MHz, use constant impedance line stretcher with a RF short as the variable load.

d) Select the value for the attenuator that will produce the test VSWR required by the appropriate applicable standard.

e) Calibrate the variable load using the network analyzer at the frequencies of interest.

f) Set the center frequency of the spectrum analyzer to the center of the test



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bandwidth, key the transmitter into the 50 Ω load, and set the level of the RF output to a full scale reference line.

g) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
2) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = Positive peak with peak hold.

h) Key the transmitter into the variable load. Vary the phase angle of the load over 360 degrees with the line stretcher. Record the frequency and level of the highest unwanted spurious emission on the spectrum analyzer.

i) Replace the transmitter under test with the RF signal generator. Replace the variable attenuator with the 50 Ω termination and adjust the signal level from the RF signal generator to reproduce the frequency and level of the highest unwanted spurious emission recorded in step h). Record this level in dBm.

j) The level recorded in step i) is the absolute level of conducted spurious emission. The conducted spurious emission into VSWR can be calculated by the following:

*conducted spurious emission (dB) =*

$$10\log_{10}\left(\frac{TX\ \ power\ \ in\ Watts}{0.001}\right) - the\ levels\ in\ step\ i)$$

### 2.2.12 Transmitter Power and Encoder Attack Time

#### 2.2.12.1 Definition

Transmitter power and encoder attack time is the time required for a transmitter to prepare and transmit information on the radio channel after changing state from standby to transmit. This test applies to a transceiver in the conventional mode of operation.



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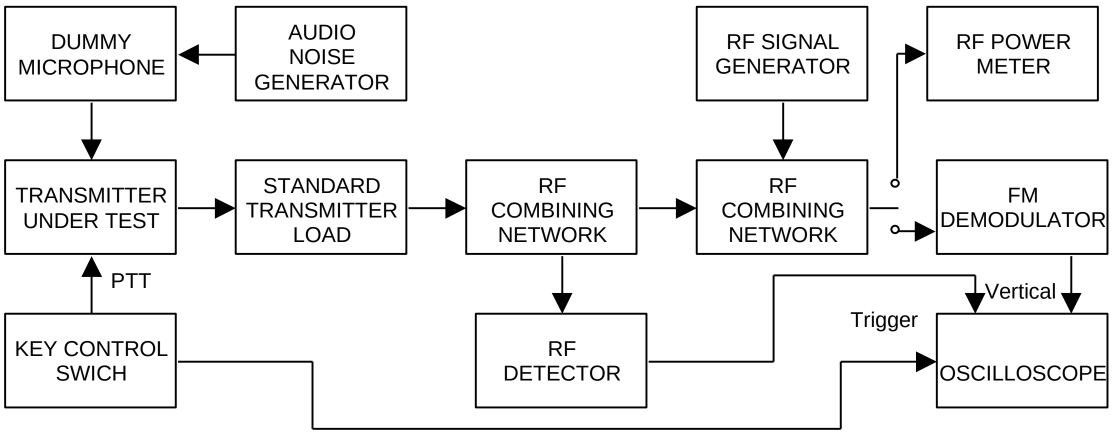
2.2.12.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Connect the FM demodulator output port to a vertical input channel of the storage oscilloscope. Connect the output of the transmitter key control to the trigger of the storage oscilloscope, and to the push-to-talk control on the transmitter under test. Add in the 1.5 ms time constant to the RF detector, and connect its output to a vertical input of the storage oscilloscope.

c) Adjust the level of the audio noise generator to the value obtained in the transmitter electrical audio performance measurement.

d) Set the FM demodulator bandwidth so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥15 kHz, and tune the frequency to the transmitter assigned frequency.

e) Set the signal generator to the assigned transmitter frequency, turn off any modulation, and set the output level to 40 dB ±1 dB below the maximum allowed input power of the FM demodulator.

f) Turn the transmitter on.

g) Supply sufficient attenuation via the RF attenuator to provide an input level to the FM demodulator that is 10 dB ±1 dB below the maximum allowed input power of the FM demodulator.

h) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the FM demodulator.



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i) Set the horizontal sweep of the oscilloscope to 20 ms per division and adjust the display to continuously view the transmitted data. Adjust the amplitude control of the oscilloscope for convenient viewing of the trace information.

j) Turn the transmitter off.

k) Adjust the oscilloscope so it will trigger on the push-to-talk signal from the transmitter key control when the transmitter key control is activated. Set the controls to store the display.

l) Repeat steps m), n), o), and p) a sufficient number of times to collect 10 data samples.

m) Turn on the transmitter and observe the stored display.

n) Measure the time interval for the transmitter output power to reach 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope). Record this value.

o) Expand the stored display to 1 ms per division and scan the stored display from left to right to find the beginning of the initial frame synchronization word. The frame synchronization word is:

 +3, +3, +3, +3, +3, -3, +3, +3, -3, -3, +3, +3, -3, -3, -3, -3, +3, -3, +3, -3, -3, -3, -3, -3,

 where +3 is the highest of the four transmission levels and -3 is the lowest of the four transmission levels.

p) Read the elapsed time from the trigger initiated by the transmitter key control to the peak of the rising edge of the first symbol of the frame synchronization word. Record this value.

q) The average value of the 10 samples recorded in step n) is the transmitter power attack time. The average value of the 10 samples recorded in step p) is the transmitter encoder attack time.



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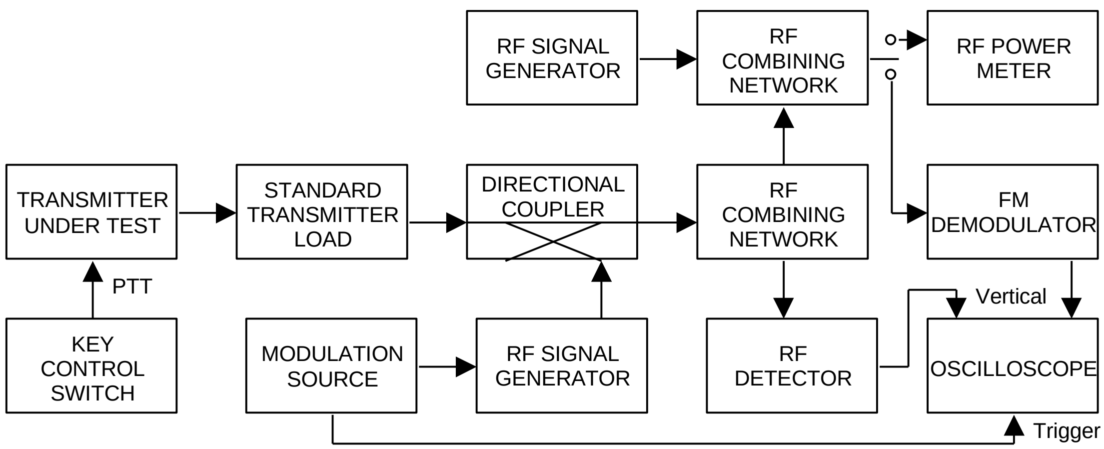
## 2.2.13 Transmitter Power and Encoder Attack Time with Busy/Idle Operation

2.2.13.1 Definition

Transmitter power and encoder attack time with busy idle operation is the time required for a transmitter to prepare and transmit information on the radio channel after the receiving channel changes state from busy to idle. This test applies to a transceiver operating such that transmissions are inhibited until a status symbol indicates an idle channel.

2.2.13.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Connect the FM demodulator output port to a vertical input channel of the storage oscilloscope. Connect the second output of the modulation source to the trigger of the storage oscilloscope. Add in the 1.5 ms time constant to the RF detector, and connect its output to a vertical input of the storage oscilloscope.

c) Set the RF generator that is connected to the directional coupler to the assigned receiver frequency and adjust the output so that the level as measured at the receiver input is -47 dBm. This signal generator level shall be maintained throughout the test.

d) Set the FM demodulator bandwidth so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥15 kHz, and tune the frequency to the transmitter assigned frequency.

e) Set the other signal generator to the assigned transmitter frequency, turn off



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any modulation, and set the output level to 40 dB ±1 dB below the maximum allowed input power of the FM demodulator.

f) Turn the transmitter on.

g) Supply sufficient attenuation via the RF attenuator to provide an input level to the FM demodulator that is 10 dB ±1 dB below the maximum allowed input power of the FM demodulator.

h) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the FM demodulator.

i) Set the horizontal sweep of the oscilloscope to 20 ms per division and adjust the display to continuously view the transmitted data. Adjust the amplitude control of the oscilloscope for convenient viewing of the trace information. Perform similar adjustment for the RF detector channel such that the detected transmitter power (off to on) may be conveniently viewed.

j) Turn the transmitter off.

k) Adjust the oscilloscope to trigger simultaneously with a change of modulation from the standard busy test pattern to the standard idle test pattern. Set the controls to store the display.

l) Modulate the RF signal generator that is connected to the directional coupler with the standard busy test pattern. Close the transmitter key control.

m) Repeat steps n), o), p), and q) a sufficient number of times to collect 10 data samples.

n) Change the modulation source from the standard busy test pattern to the standard idle test pattern to initiate the measurement. Observe the stored display on the oscilloscope.

o) Measure the time interval from the trigger initiated by the modulation change for the transmitter output power to reach 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope). Record this value.

p) Expand the stored display to 1 ms per division and scan the stored display from left to right to find the beginning of the initial frame synchronization word. The frame synchronization word is:



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+3, +3, +3, +3, +3, -3, +3, +3, -3, -3, +3, +3, -3, -3, -3, -3, +3, -3, +3, -3, -3, -3, -3, -3,

where +3 is the highest of the four transmission levels and -3 is the lowest of the four transmission levels.

q) Read the elapsed time from the trigger initiated by the modulation change to the peak of the rising edge of the first symbol of the frame synchronization word. Record this value.

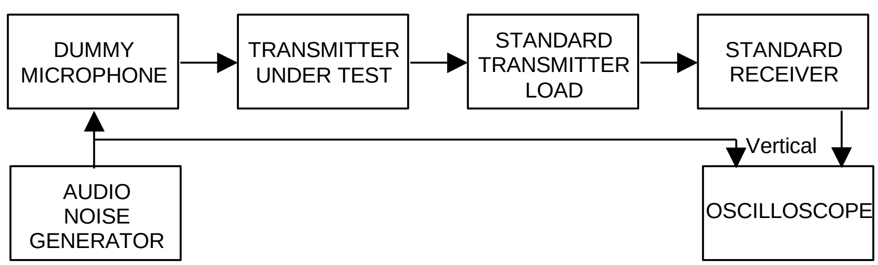
r) The average value of the 10 samples recorded in step o) is the transmitter power attack time with busy idle operation. The average value of the 10 samples recorded in step q) is the transmitter encoder attack time with busy idle operation.

## 2.2.14 Transmitter Throughput Delay

### 2.2.14.1 Definition

The transmitter throughput delay is the time it takes for audio changes in the microphone to be encoded and transmitted over the air. Because the nature of changes in a digital audio signal are quite complex, a calibrated receiver with a known receiver throughput delay is used to monitor the transmitted signal. The aggregate delay of the transmitter under test and calibrated receiver can then be measured, and the desired transmitter throughput delay is then the aggregate delay less the delay of the calibrated receiver.

### 2.2.14.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Connect the output of the standard receiver to a vertical channel of the oscilloscope. Monitor the audio noise generator output on another vertical channel of the oscilloscope.



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c) Repeat steps d) and e) enough times to collect 10 data samples.

d) Switch the output of the noise generator from no signal to a band limited pink noise signal with an rms voltage equal to the level measured in the transmitter electrical audio performance measurement. Trigger the oscilloscope from the vertical channel that monitors the noise generator output.

e) Measure the time between when the noise generator output is activated and when a noise signal is observed at the standard receiver output. Record this value.

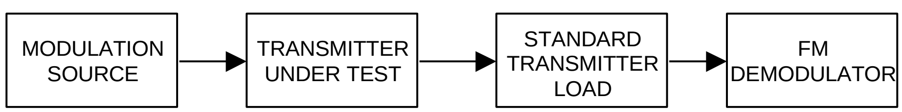
f) The transmitter throughput delay is the average of the 10 samples recorded in step e) less the receiver throughput delay of the standard receiver.

## 2.2.15 Frequency Deviation for C4FM

### 2.2.15.1 Definition

Frequency deviation for C4FM is the amount of frequency deviation that results from both a test pattern of low deviation symbols, and a test pattern of high deviation symbols. This test applies only to transmitters employing C4FM modulation.

### 2.2.15.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter symbol rate pattern.

c) Set the FM demodulator to measure peak positive deviation. Set the audio bandwidth so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥3 kHz. Turn the de-emphasis function off.

d) Record the peak positive deviation as $f_1$.

e) Set the FM demodulator to read peak negative deviation.



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f) Record the peak negative deviation as $f_2$.

g) The frequency deviation for C4FM high level is calculated by the following:

*frequency deviation high level positive peak* $= f_1$
*frequency deviation high level negative peak* $= f_2$

h) Modulate the transmitter with the standard low deviation test pattern.

i) Set the FM demodulator to measure peak positive deviation.

j) Record the peak positive deviation as $f_3$.

k) Set the FM demodulator to read peak negative deviation.

l) Record the peak negative deviation as $f_4$.

m) The frequency deviation for C4FM low level is calculated by the following:

*frequency deviation low level positive peak* $= f_3$
*frequency deviation low level negative peak* $= f_4$

### 2.2.16 Modulation Fidelity

2.2.16.1 Definition (Combined Method for C4FM, CQPSK, or a linear simulcast modulation)

Modulation fidelity is the degree of closeness to which the modulation follows the desired ideal theoretical modulation. The fidelity is determined from observations of the signal at the output of an integrate and dump filter, that is preceded by an FM demodulator. The filtered FM modulation trajectories for C4FM, CQPSK, or a linear simulcast modulation are different at all points in time except at the symbol decision points.

The modulation fidelity is measured by determining the rms difference between the actual signal, and the ideal C4FM deviation for the transmitted symbols as given in table 7:



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Table 7
C4FM Deviation

| Information Bits | Symbol | C4FM Deviation |
|---|---|---|
| 01 | +3 | +1.8 kHz |
| 00 | +1 | +0.6 kHz |
| 10 | -1 | -0.6 kHz |
| 11 | -3 | -1.8 kHz |

Let $s_k$ represent the C4FM deviation of the transmitted symbols, and $z_k$ represent the detected signal at the sampling instants. The transmitter can then be modeled as:

$$z_k = C0 + C1 * (s_k + e_k)$$

where:

*C0* is a constant representing a carrier frequency offset.

*C1* is a constant representing deviation errors resulting from gain errors in the transmitter's modulator or baseband signal processing.

$e_k$ is the residual deviation error.

The sum-square deviation error is then:

$$\sum_{k=MIN}^{k=MAX} |e_k|^2 = \sum_{k=MIN}^{k=MAX} \left| \frac{z_k - CO}{C1} - s_k \right|^2$$

*C0* and *C1* are chosen to minimize the sum-square deviation error. The phase of the symbol clock used to determine $z_k$ shall also be chosen for minimum error.

Parameters reported are:

Carrier frequency offset: *C0*

Deviation: *C1**1.8 kHz



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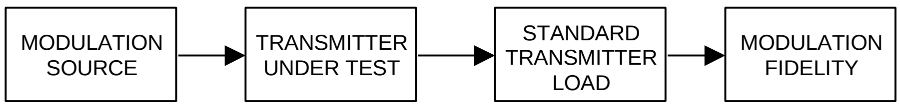
rms deviation error: The square root of the sum-square deviation error divided by the number of symbols in the summation, expressed as a percentage of the deviation.

2.2.16.2 Method of Measurement (Combined Method for C4FM,CQPSK, or a linear simulcast modulation.)




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter test pattern.

c) Trigger the measurement.

d) Capture at least a 144 bit segment of the waveform.

e) Record the deviation, carrier frequency offset, and rms deviation error.

f) The parameters recorded in step e) are the modulation fidelity parameters.

2.2.16.3 Definition (Method for C4FM)

Modulation fidelity is the degree of closeness to which the modulation follows the desired ideal theoretical modulation. The fidelity is determined by comparing the spectrum of the signal at the output of an FM demodulator to the spectrum of an ideal C4FM modulating signal. This method is an optional method that may be used in place of the combined C4FM and CQPSK method for C4FM transmitters.

The standard transmitter C4FM modulation fidelity pattern produces a comb spectrum similar to that shown below. This is the standard transmitter C4FM modulation fidelity spectrum. This spectrum includes the effects of both the Nyquist filter H(f), and the shaping filter P(f).



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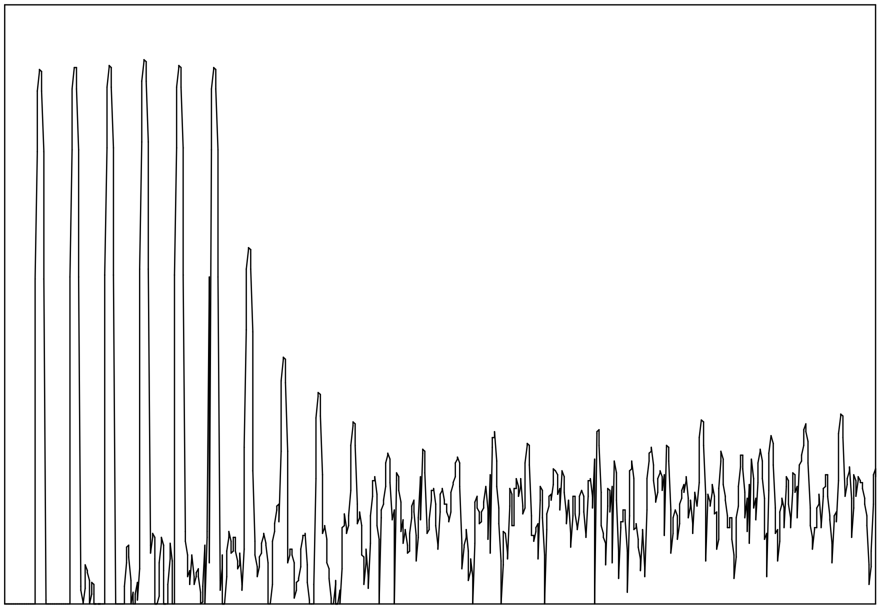

C4FM Spectrum

Let *Y(f)* be the standard transmitter C4FM modulation fidelity spectrum, and X(f) be the spectrum at the output of the FM demodulator. Then the weighted mean-square vector error is:

$$\sum_{k=1}^{k=7} \left|E_k\right|^2 = \sum_{k=1}^{k=7} \left| \frac{X_k e^{j2\pi f_k C0}}{C1} - Y_k \right|^2 \left|D_k\right|^2$$

where:

*C0* is a constant representing delay in the measurement of Y(f).

*C1* is a constant representing deviation errors resulting from gain errors in the transmitter's modulator or baseband signal processing.

$f_k$ is the set of frequencies included in the standard transmitter C4FM modulation fidelity spectrum

$Y_k = Y(f_k)$

$X_k = X(f_k)$

$D_k = D(f_k)$ where *D(f)* is the response of the integrate and dump filter described in section 9.6 of the Common Air Interface



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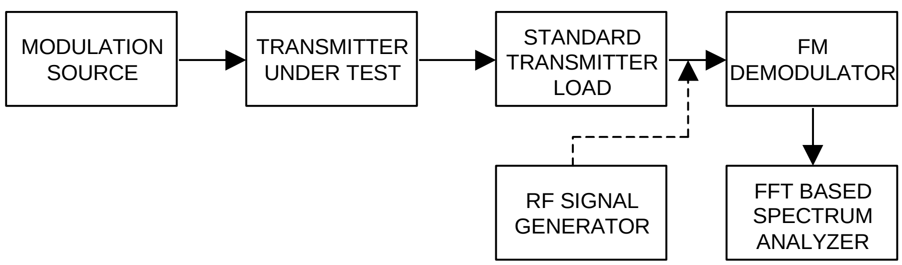
$E_k$ is the residual error vector.

*C0* and *C1* are chosen to minimize the sum-square error.

Parameters reported are:

| | |
|---|---|
| Deviation | *C1* * 1.8 kHz |
| rms Error Magnitude: | square root of the sum-square error divided by the number of frequency points used in the summation, expressed as a percentage of 1 kHz |
| Peak spurious | Largest spectral component in *X(f)* not listed as part of the standard transmitter C4FM modulation fidelity spectrum. |

2.2.16.4 Method of Measurement (Method for C4FM)




a) Connect the equipment as illustrated.

b) Connect the FM demodulator input to the signal generator. On the FM demodulator, turn off de-emphasis and disable all low-pass and high-pass filters. Select a modulation range greater than or equal to 4 kHz.

c) Set the signal generator to the assigned transmitter frequency and modulate it with a 400 Hz tone with ±4 kHz peak deviation.



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d) Connect the output of the FM demodulator to the spectrum analyzer. Set the spectrum analyzer for a span of 0 Hz to 10 kHz, and a time record length greater than or equal to 80 ms. Select a high accuracy window, such as a flat top window. Alternatively, use a Hanning window and a time record length of 80 ms. The selection of time record length and window must result in a resolution bandwidth greater than 18 Hz. Set the spectrum analyzer input coupling to ac.

e) Trigger the measurement.

f) Divide the amplitude of the spectral component at 400 Hz by the deviation 4000 Hz and record the result as the system calibration factor (e.g. 1.01 V/kHz).

g) Connect the FM demodulator input to the standard transmitter load.

h) Modulate the transmitter with the standard C4FM modulation fidelity pattern.

i) Trigger the measurement.

j) Record the amplitudes of the real and imaginary components for all frequencies defined in the standard transmitter C4FM modulation fidelity spectrum.

k) Divide the results obtained in step (j) by the calibration factor obtained in step (f) and record as $X_k$ where $k$ is the frequency index as defined for the standard transmitter C4FM modulation fidelity spectrum. Use results to compute the deviation and rms error magnitude

l) Record the magnitude of the largest spectral element (noise or tone) at a frequency not defined as part of the standard transmitter C4FM modulation fidelity spectrum. Divide the magnitude by the calibration factor and record as the peak spurious.

### 2.2.17 Symbol Rate Accuracy

2.2.17.1 Definition

Symbol rate accuracy is the ability of the transmitter to operate at the assigned 4800 symbols per second rate.



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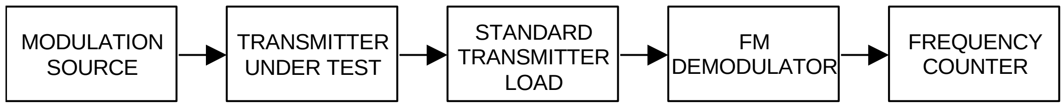
2.2.17.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Operate the equipment in standby condition for at least 15 minutes before proceeding.

c) Modulate the transmitter with the standard transmitter symbol rate pattern.

d) Record the measured frequency as $MBR_{Hz}$.

e) Calculate the ppm symbol rate error by the following:

$$ppm\ error = \left( \frac{MBR_{Hz}}{1200} - 1 \right) * 10^6$$

f) The value calculated in step e) is the symbol rate error.

## 2.2.18 Transient Frequency Behavior

2.2.18.1 Definition

Transient Frequency Behavior is a measure of the difference, as a function in time, of the actual transmitter frequency to the assigned transmitter frequency when the transmitted RF output power is switched on or off.



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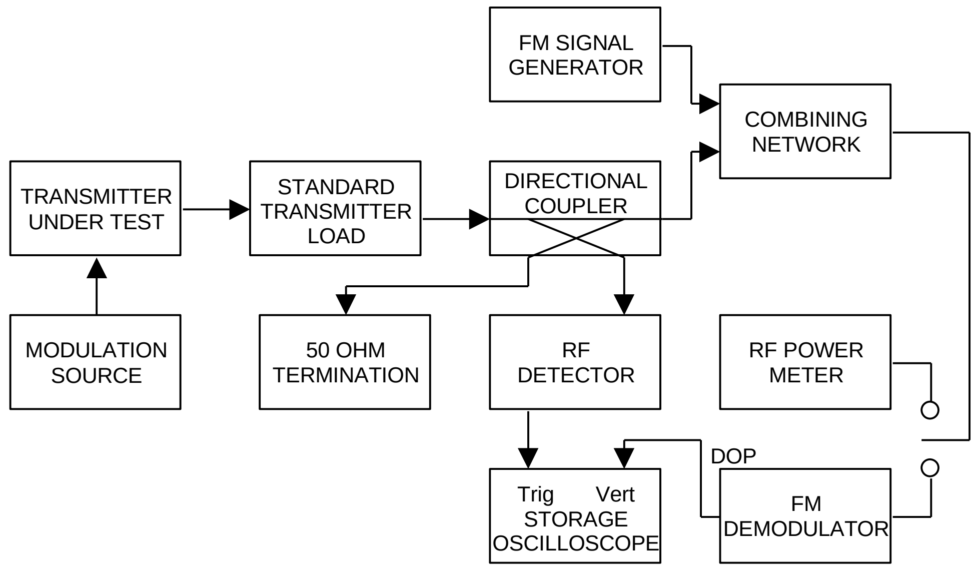
2.2.18.2 Method of Measurement




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter low deviation pattern.

c) Connect the FM demodulator output to the vertical input channel of the storage oscilloscope. Connect the output of the RF peak detector to the external trigger on the storage oscilloscope. Connect the output of the RF combining network to the RF power meter.

d) Set the FM demodulator to measure FM deviation with the audio bandwidth set so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥15 kHz, and tune the RF frequency to the transmitter assigned frequency.

e) Set the signal generator to the assigned transmitter frequency and modulate it with a 1 kHz tone at ±12.5 kHz deviation and set its output level to -100 dBm.

f) Turn the transmitter on.

g) Supply sufficient attenuation via the RF attenuator to provide an input level to the FM demodulator that is 40 dB ±1 dB below the FM demodulator maximum allowed input power when the transmitter is operating at its rated



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power level. Note this power level on the RF power meter.

h) Turn the transmitter off.

i) Adjust the RF level of the signal generator to provide RF power into the RF power meter equal to the level noted in step g). This signal generator RF level shall be maintained throughout the rest of the measurement.

j) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the FM demodulator.

k) Set the horizontal sweep rate on the storage oscilloscope to 10 ms per division and adjust the display to continuously view the 1 kHz tone from the FM demodulator. Adjust the vertical amplitude control of the oscilloscope to display the 1 kHz at ±4 divisions vertically centered on the display. Turn off the 1 kHz modulation on the signal generator.

l) Adjust the oscilloscope so it will trigger on an increasing magnitude from the RF peak detector at 1 division from the left side of the display, when the transmitter is turned on. Set the controls to store the display.

m) Reduce the attenuation of the RF attenuator so the input to the RF peak detector and the RF combiner is increased by 30 dB when the transmitter is turned on.

n) Turn on the transmitter and observe the stored display. The output at the FM demodulator, due to the change in the ratio of power between the signal generator input power and the transmitter output power will, because of the capture effect of the FM demodulator, produce a change in display. For the first part of the sweep it will show a straight line (residual hum and noise of the unmodulated signal). Then, once the FM demodulator has been captured by the transmitter power, the display will show the frequency difference from the assigned frequency to the actual transmitter frequency versus time. The instant when the transmitter bit rate pattern envelope predominates (including any capture time due to phasing) is considered to be $t_{on}$. The trace shall be maintained within the allowed divisions during the period $t_1$ and $t_2$ (defined in **[R2]** clause 3.2.18 Transient Frequency Behavior).

o) Turn on the transmitter and observe the stored display. The average of the positive and negative peak of the signal trace shall be maintained within the allowed divisions after the end of $t_2$ and remain within it until the end of the trace.

p) To test the transient frequency behavior during the period $t_3$ , the transmitter



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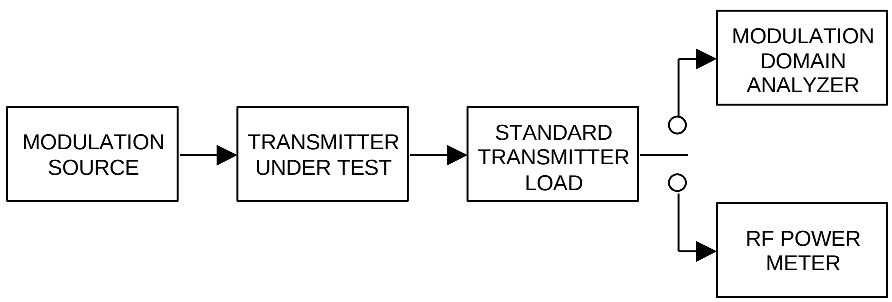
shall be switched on.

q) Adjust the oscilloscope trigger controls so it will trigger on a decreasing magnitude from the RF peak detector, at 1 division from the right side of the display, when the transmitter is turned off. Set the controls to store the display. The moment when the demodulated envelope transitions to a straight line (residual hum and noise of the unmodulated signal) is considered to be $t_{off}$.

r) Turn the transmitter off.

s) Observe the display. The average of the positive and negative peaks of the signal trace shall remain within the allowed divisions during period $t_3$ (defined in **[R2]** clause 3.2.18 Transient Frequency Behavior).

2.2.18.3 Alternate Method of Measurement (Using a Modulation Domain Analyzer)




a) Connect the equipment as illustrated.

b) Modulate the transmitter with the standard transmitter symbol rate pattern.

c) Connect the output of the standard transmitter load to the RF power meter. Supply sufficient attenuation via the RF attenuator to provide a level that is approximately 40 dB below the maximum allowable input to the modulation domain analyzer.

d) Turn the transmitter off.

e) Disconnect the RF power meter and connect the modulation domain analyzer in its place. Set the envelope trigger of the modulation domain analyzer to the minimum level that will trigger when the transmitter is keyed.

f) Reduce the attenuation of the RF attenuator so that the input to the to the modulation domain analyzer is increased by 30 dB when the transmitter is



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turned on.

g) Set the modulation domain analyzer to trigger on the rising edge of the waveform in order to capture a single-shot turn-on of the transmitter signal.

h) Adjust the display of the modulation domain analyzer for proper viewing of the transmitter transient behavior. Set the timebase reference to the left for observing the transmitter turn-on transient.

i) Turn the transmitter on.

j) Observe the stored display of the modulation domain analyzer. The average of the positive and negative peak of the signal trace shall be maintained within the allowable limits during the periods $t_1$ and $t_2$, and shall also remain within limits following $t_2$.

k) Adjust the modulation domain analyzer to trigger on the falling edge of the transmitter waveform in order to capture a single-shot turn-off transient of the transmitter signal.

l) Adjust the display of the modulation domain analyzer for proper viewing of the transmitter transient behavior. Set the timebase reference to the right for observing the transmitter turn-off transient.

m) Turn off the transmitter.

n) Observe the stored display of the modulation domain analyzer. The average of the positive and negative peak of the signal trace shall be maintained within the allowable limits during the period $t_3$.

### 2.2.19 RFSS Throughput Delay

2.2.19.1 Definition

The RFSS throughput delay is the time delay of audio to be relayed through an RF Sub-System (RFSS) from the input to the output. The input and the output of the RFSS are taken to be radio channels in this measurement. Typically, there is a single radio channel, consisting of a transmit/receive frequency pair for a base station, and the RFSS throughput delay is the delay through both.



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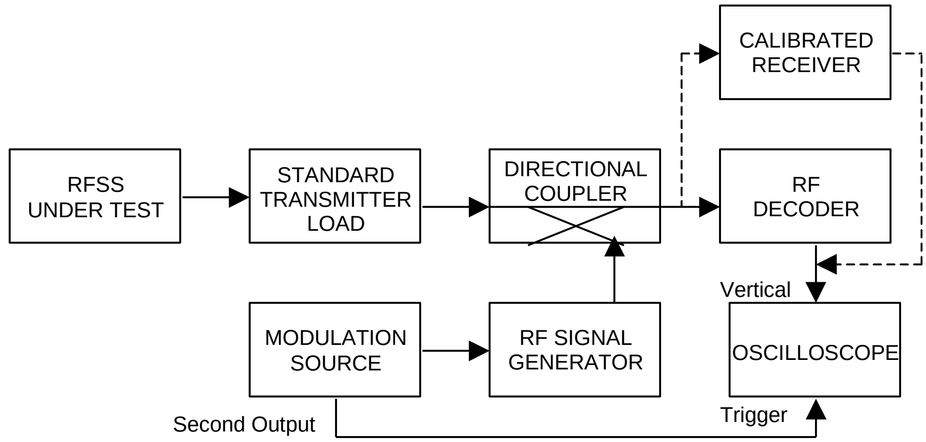
2.2.19.2 Method of Measurement




a) Connect the equipment as illustrated. Configure the RFSS to gate the CAI voice frames on the RF input to the RF output. Note that in a repeater, this configuration is standard. In a trunked RFSS, it may be necessary to alter the RFSS slightly to allow CAI voice frames to be so gated. Two alternative set-ups are given:

   1. An RF decoder may be used in one alternative. In this case, the measurement on the oscilloscope is to the start of a frame synchronization word.

   2. A calibrated receiver may be used instead of an RF demodulator. The receiver throughput delay should be calibrated according to 2.1.18, so that the receiver delay can be subtracted from the overall delay measurement.

b) Set the RF signal generator to the frequency of the inbound channel of the RFSS, and adjust the output such that the level at the receiver terminals is the standard input signal level. This signal generator level shall be maintained throughout the test.

c) Modulate the signal generator with the standard silence test pattern. Configure the modulation to switch to the standard tone test pattern on command, at an Link Data Unit (LDU) boundary, and configure the second output signal to indicate the LDU boundary of the switch.

d) Set the RF decoder to the frequency of the outbound channel from the RFSS.

e) Set the oscilloscope to trigger when the signal generator modulation source



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switches from the standard silence pattern to the standard tone test pattern. When the oscilloscope triggers, it should record the decoder output. Set the sweep for 20 ms per division.

f) Repeat steps g), h), and i) a sufficient number of times to collect 10 data samples.

g) Switch the modulation source from the standard silence test pattern to the standard tone test pattern. This should trigger the oscilloscope.

h) In the case of the RF demodulator: Measure the time from the oscilloscope trigger to the beginning of the frame synchronization word that contains the tone test pattern.

In the case of the calibrated receiver: On the oscilloscope measure the time from the oscilloscope trigger to the beginning of the tone output from the test receiver. Subtract the receiver delay of the calibrated test receiver.

i) Switch the modulation source back to the standard silence test pattern.

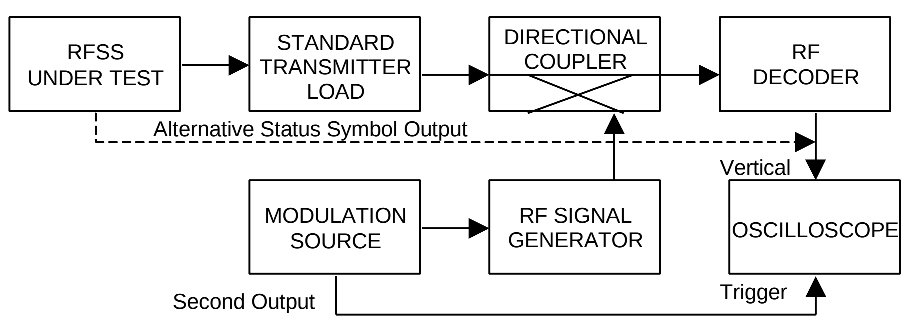
j) The RFSS throughput delay is the average of the times recorded in step h).

### 2.2.20 RFSS Idle to Busy Transition Time

2.2.20.1 Definition

The RF Sub-System (RFSS) idle to busy time is the time required for a base station to transmit a status symbol indicating a busy state after a radio channel has activity.

2.2.20.2 Method of Measurement




a) Connect the equipment as illustrated. Two methods of keying the RFSS transmitter without receive channel activity are allowed. In the first way,



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the RFSS should be configured so that the transmitter "hangs" and continues transmitting while the RF input is inactive. During this hang time, the status symbols should indicate an idle channel. In the second way, the RFSS should be keyed from a wireline, such as may be done for console operation, or for Fixed Network Equipment (FNE) data operation. While the station is keyed in this way, the status symbols should indicate an idle channel. An alternative to the setup shown in the figure includes the following:

1. The RFSS may provide an output with status symbol information that can be analyzed in the measurement to determine slot boundaries. The RFSS output of status symbols should have a known time delay relationship with the actual transmitted signal.

2. A digital logic analyzer may be used instead of an oscilloscope if the status symbol information is present in a digital manner in the test set up.

b) Set the RF signal generator to the frequency of the inbound channel of the RFSS, and adjust the output such that the level at the receiver terminals is the standard input signal level. Switch the RF output off.

c) Configure the modulation source so that when the signal generator is switched on, it generates the standard tone test pattern beginning at an Link Data Unit (LDU) boundary. Configure the second output of the modulation source to indicate the LDU boundary at the start of the signal.

d) Set the oscilloscope to trigger when the signal generator switches on. Set the sweep for 10 ms per division. The oscilloscope should record the status symbols at the output of the demodulator.

e) Set the RF decoder to decode the status symbols so that they may be recorded by the oscilloscope, or alternatively connect the alternate status symbol of the RFSS to the oscilloscope. Repeat step f) a sufficient number of times to collect 10 data samples.

f) Activate the RF generator to begin a brief transmission. The oscilloscope should trigger and record the transition of the status symbols from IDLE to BUSY. Note that the status symbol value encoding an UNKNOWN status is allowed, but that these status symbols are not counted in the measurement. Measure the time from the beginning of the oscilloscope trigger to when the status symbol at the RFSS output indicates a BUSY channel. Switch the signal generator off, so that the RFSS remains keyed while indicating an IDLE channel.



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g) The RFSS idle to busy transition time is the average of the times measured in step f).



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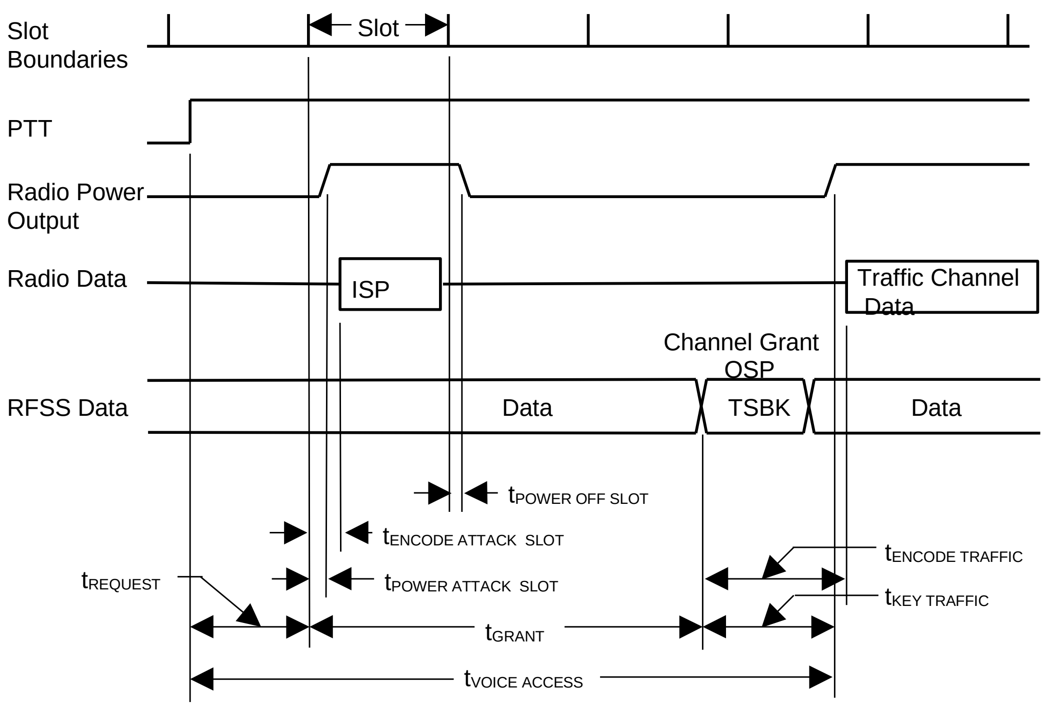
## 2.3 Methods of Measurement for Trunking Systems

This section details test definitions and methods of measurement of the characteristics of digital land mobile trunking system equipment including vehicular (mobile), handheld (portable), and fixed network equipment employing C4FM, CQPSK, or a linear simulcast modulation, a vocoder, with or without encryption.

Many of the tests in this section involve timing measurements that are done on trunking equipment and systems. Many of these timing parameters are interdependent, and as such, there may be a difficulty in visualizing the interdependence. The following figure is helpful in visualizing the various timing parameters and their relationship:




Trunking System Timing Parameters



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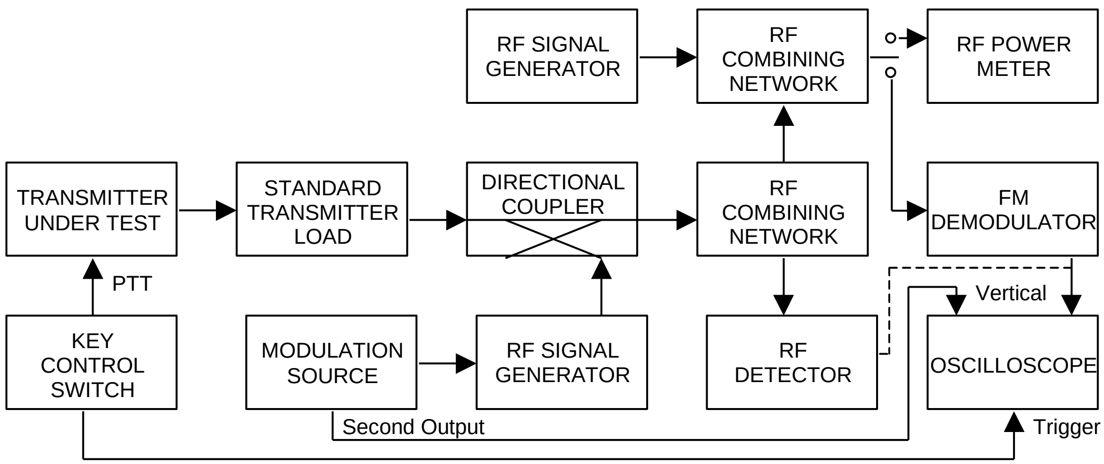
## 2.3.1 Trunking Control Channel Slot Times

### 2.3.1.1 Definition

The trunking control channel slot time is a measure of how well a subscriber radio inserts an inbound signalling packet (ISP) into a slot on the trunking control channel. This parameter consists of three separate measurements; RF power attack time, RF power turn off time, and encoder attack time.

### 2.3.1.2 Method of Measurement




a) Connect the equipment as illustrated. The radio shall be set for trunking operation. Connect the FM demodulator output port to a vertical input channel of the storage oscilloscope. Connect the second output of the modulation source to a vertical input of the oscilloscope.

b) Set the RF generator that is connected to the directional coupler to the frequency of the outbound control channel and adjust the output so that the level at the receiver terminals is the standard input signal level. This signal generator level shall be maintained throughout the test.

c) Set the FM demodulator bandwidth so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥15 kHz, and tune its frequency to the frequency of the inbound control channel.

d) Set the other signal generator frequency to the frequency of the inbound control channel, turn off any modulation, and set the output level to 40 dB ±1 dB below the maximum allowed input power of the FM demodulator.



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e) Turn the transmitter on.

f) Supply sufficient attenuation via the RF attenuator to provide an input level to the FM demodulator that is 10 dB ±1 dB below the maximum allowed input power of the FM demodulator.

g) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the FM demodulator.

h) Connect the output of the transmitter key control to the trigger of the storage oscilloscope, and to the push-to-talk control on the transmitter under test. Set the horizontal sweep of the oscilloscope to 10 ms per division and adjust the display to continuously view the transmitted data. Adjust the amplitude control of the oscilloscope for convenient viewing of the trace information.

i) Turn the transmitter off.

j) Adjust the oscilloscope to trigger simultaneously with the push-to-talk signal from the transmitter key control. Set the controls to store the display.

k) Modulate the RF signal generator that is connected to the directional coupler with the standard RFSS broadcast signal. The second output of the modulation source shall be set for the trigger on slot boundary pattern.

l) Repeat steps m), n), and o) enough times to collect 10 data samples.

m) Turn on the transmitter and observe the stored display on the oscilloscope.

n) Expand the stored display to 1 ms per division and scan the stored display from left to right to find the beginning of the initial frame synchronization word. The frame synchronization word is:

   +3, +3, +3, +3, +3, -3, +3, +3, -3, -3, +3, +3, -3, -3, -3, -3, +3, -3, +3, -3, -3, -3, -3, -3,

   where +3 is the highest of the four transmission levels and -3 is the lowest of the four transmission levels.

o) Read the elapsed time from the nearest slot boundary marker to the peak of the rising edge of the first symbol of the frame synchronization word. Record this value.

p) Add in the 1.5 ms time constant to the RF detector, and connect its output to a vertical input of the storage oscilloscope to replace the FM demodulator.



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q) Turn the transmitter on. Set the horizontal sweep of the oscilloscope to 10 ms per division and adjust the display such that the detected transmitter power (off to on) may be conveniently viewed.

r) Turn the transmitter off.

s) Adjust the oscilloscope to trigger simultaneously with the push-to-talk signal from the transmitter key control. Set the controls to store the display.

t) Repeat steps u), v), and w) enough times to collect 10 data samples.

u) Turn on the transmitter and observe the stored display on the oscilloscope.

v) Measure the time interval from the nearest slot boundary immediately preceding or coincident with the rising edge of the power envelope to when the transmitter output power reaches 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope). The slot boundary used for this measurement is referenced in step w). The measured time may be zero or positive; it cannot be negative. Record this value.

w) Measure the time interval from the slot boundary immediately following the reference boundary used in step v) to when the transmitter output power drops to 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope). This time measurement may be positive (indicating that the power falls after the slot boundary), negative (indicating that power falls before the slot boundary), or zero. Record this value.

x) The average of the 10 samples recorded in step o) is the trunking control channel encode attack slot time. The average of the 10 samples recorded in step v) is the trunking control channel RF power attack slot time. The average of the 10 samples recorded in step w) is the trunking control channel RF power turn off slot time.



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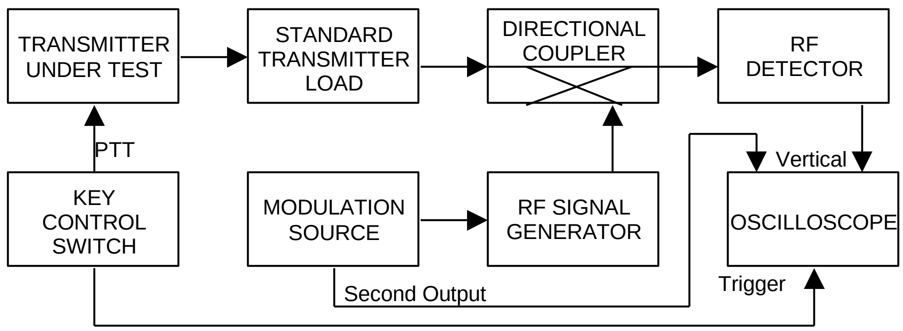
### 2.3.2 Trunking Request Time

2.3.2.1 Definition

Trunking request time for a subscriber radio is the time from the initiation of a user push-to-talk until a channel request is sent on the control channel.

2.3.2.2 Method of Measurement




a) Connect the equipment as illustrated. The radio shall be set for trunking operation.

b) Set the RF generator to the frequency of the outbound control channel and adjust the output so that the level at the receiver terminals is the standard input signal level. This signal generator level shall be maintained throughout the test.

c) Modulate the RF signal generator with the standard RFSS broadcast signal. The second output of the modulation source shall be set for the trigger on slot boundary pattern.

d) Add in the 1.5 ms time constant to the RF detector, and connect its output to a vertical input of the storage oscilloscope. Connect the output of the transmitter key control to the trigger of the storage oscilloscope, and to the push-to-talk control on the transmitter under test.

e) Turn the transmitter on. Set the horizontal sweep of the oscilloscope to 10 ms per division and adjust the display such that the detected transmitter power (off to on) may be conveniently viewed.

f) Turn the transmitter off.

g) Adjust the oscilloscope to trigger simultaneously with the push-to-talk



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signal from the transmitter key control. Set the controls to store the display.

h) Repeat steps i) and j) enough times to collect 10 data samples.

i) Turn on the transmitter and observe the stored display on the oscilloscope.

j) Measure the time interval from the trigger signal from the push-to-talk to the slot boundary pattern marker just prior to or coincident with the transmitter output power reaching 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope) on the control channel. Record this value.

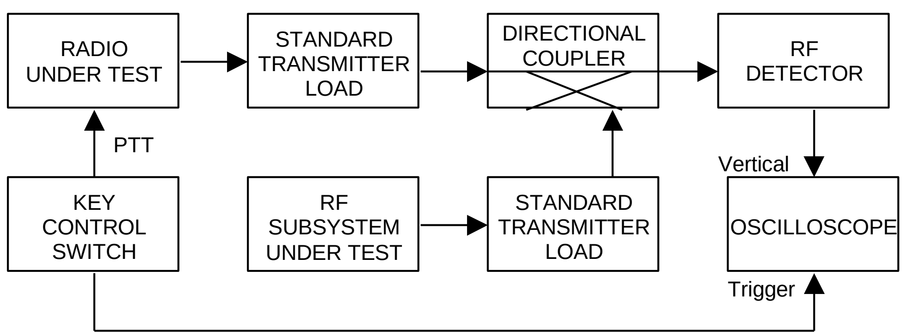
k) The average of the 10 samples recorded in step j) is the trunking request time.

### 2.3.3 Trunking Voice Access Time

2.3.3.1 Definition

Trunking voice access time is the time required from the initiation of a user push-to-talk until a traffic channel is granted, and transmission on that channel has begun. This measurement includes the time for both the subscriber equipment and the RF subsystem equipment.

2,3,3,2 Method of Measurement




a) Connect the equipment as illustrated. The radio shall be set for trunking operation. Add sufficient attenuation for both the radio under test and the RF subsystem under test so that the level at each set of receiver terminals is at a level of approximately -47 dBm.

b) Add in the 1.5 ms time constant to the RF detector, and connect its output to a vertical input of the storage oscilloscope. Connect the output of the



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transmitter key control to the trigger of the storage oscilloscope, and to the push-to-talk control on the transmitter under test.

c) Turn the transmitter on. Set the horizontal sweep of the oscilloscope to 10 ms per division and adjust the display such that the detected transmitter power (off to on) may be conveniently viewed.

d) Turn the transmitter off.

e) Adjust the oscilloscope to trigger simultaneously with the push-to-talk signal from the transmitter key control. Set the controls to store the display.

f) Repeat steps g) and h) enough times to collect 10 data samples.

g) Turn on the transmitter and observe the stored display on the oscilloscope.

h) Measure the time interval from the trigger signal from the push-to-talk to when the transmitter output power reaches 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope) and sustains that output on the traffic channel. Record this value.

i) The average of the 10 samples recorded in step h) is the trunking voice access time.

### 2.3.4 Time to Grant

#### 2.3.4.1 Definition

The time to grant is a measure of how fast an RF Sub-System (RFSS) responds to a request for service with a channel grant for service. The request for service is an Inbound Signaling Packet (ISP) to the RFSS. The grant for service is an Outbound Signaling Packet (OSP) from the RFSS.



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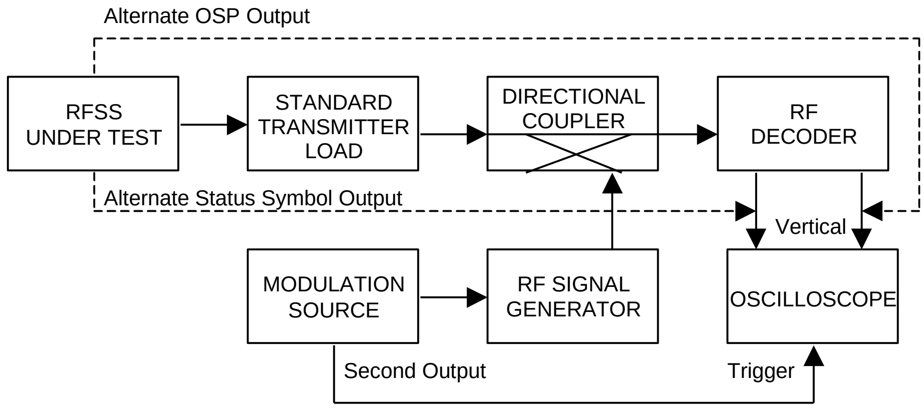
2.3.4.2 Method of Measurement




a) Connect the equipment as illustrated. Configure the RFSS to grant service on a working channel in response to a request for service without requiring the usual registration procedure for trunking systems. Also, configure the RFSS so that it has at least one free channel for service, and so that no other services are currently active. Alternatives to the set up shown in the figure include the following:

1. A suitable subscriber radio may be substituted for the combined RF decoder, modulation source, and RF signal generator. The subscriber radio should have an output to indicate an ISP transmission suitable for triggering the measurement.

2. The RFSS may provide an output with OSP information that can be analyzed by a suitable item of test equipment, such as a logic analyzer. The RFSS output of OSPs should have a known time delay relationship with the actual transmitted signal.

3. The RFSS may provide an output with Status Symbol information that can be analyzed in the measurement to determine slot boundaries. The RFSS output of status symbols should have a known time delay relationship with the actual transmitted signal.

4. A digital logic analyzer may be used instead of an oscilloscope if the status symbol and OSP information is presented in a digital manner in the test set up.

b) Set the RF signal generator to the frequency of the inbound control channel and adjust the output so that the level at the RFSS receiver terminals is the standard input signal level. The signal generator shall be maintained at this



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level throughout the test.

c) Set the RF decoder to the frequency of the outbound control channel. Configure the decoder to output slot boundary indications to the modulation source. Configure the demodulator to output channel grant indications to the oscilloscope.

d) Set the modulation source to generate the standard service request signal in synchronization to a slot boundary.

e) Set the oscilloscope to trigger on the modulation source, and record the slot boundaries and the channel grant information of the decoder. Set the sweep time to 100 ms per division.

f) Repeat steps g) and h) a sufficient number of times to collect 10 data samples.

g) Activate the modulation source to generate an ISP service request. The oscilloscope should trigger and record the slot boundaries and the OSP channel grant in response to the ISP.

h) Let T be the time from the slot boundary immediately preceding the ISP service request to the beginning of the Trunking Signal Block that encodes the channel grant OSP. If the decoder has any delays, these should be subtracted from the oscilloscope measurement to compute T. If any RFSS alternative outputs are used, the associated time delays should be included in the computation of T.

i) The time to grant is the average of the T times recorded in step h).

## 2.3.5 Transmitter Time to Key on a Traffic Channel

### 2.3.5.1 Definition

The transmitter time to key on a traffic channel is a measure of how fast a subscriber radio responds to a channel grant by keying on the assigned working channel. The grant for service is an Outbound Signal Packet (OSP) from the RF Sub-System (RFSS). The transmitter time to key on a working channel consists of two measurements: the first is the time for the RF power to be keyed on; and the second is the time for modulation to be presented on the working channel.



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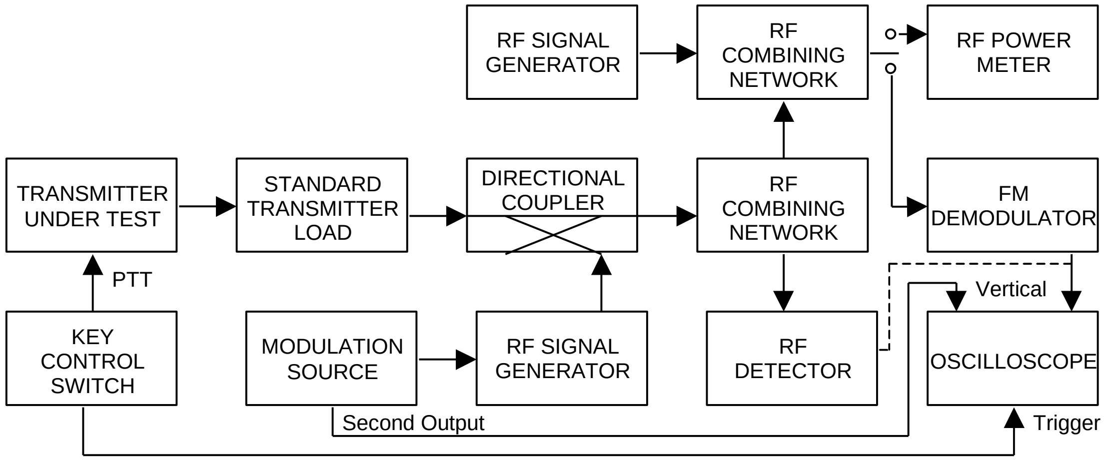
2.3.5.2 Method of Measurement




a) Connect the equipment as illustrated. Add in the 1.5 ms time constant to the RF detector. The radio shall be set for trunking operation. The radio shall be configured so that the normal registration procedure is bypassed, such that a request Inbound Signal Packet (ISP) will be generated on PTT, the radio will wait during a queued response OSP, and the radio shall respond to a channel grant OSP.

b) Set the RF signal generator that is connected to the directional coupler to the frequency of the outbound control channel and adjust the output so that the level at the receiver terminals is the standard signal level. This generator level shall be maintained throughout the test.

c) Modulate the RF signal generator that is connected to the directional coupler with the standard service grant signal. Configure the modulation to switch from a queued response OSP to a channel grant OSP on command, and configure the second output signal to indicate the start of the channel grant OSP.

d) Turn the transmitter on. Set the horizontal sweep of the oscilloscope to 20 ms per division, and adjust the display such that the detected transmitter power transition may be conveniently viewed.

e) Turn the transmitter off.

f) Adjust the oscilloscope to trigger simultaneously with the channel grant OSP transmitted by the modulation source.

g) Repeat steps h), i), and j) a sufficient number of times to collect 10 data



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samples.

h) Activate the PTT on the transmitter under test such that it transmits an ISP to request service.

i) After a short time, activate the modulation source to switch to a channel grant OSP signal. This should trigger the oscilloscope.

j) Record the time from the beginning of the OSP to the point where the transmitter output power reaches 50% of its maximum value (70.7% of the maximum voltage level displayed on the oscilloscope). Deactivate the PTT on the transmitter to release the channel.

k) The RF transmitter time to key on a working channel is the average of the times recorded in step j).

l) Set the demodulator to the channel assigned by the OSP. Set the demodulator so that the high pass corner frequency is ≤15 Hz and the low pass corner frequency is ≥15 kHz. Set the other signal generator to the frequency of the assigned channel, turn off any modulation, and set its output to -100 dBm.

m) Turn the transmitter on. Supply sufficient attenuation via the RF attenuator to provide an input level to the FM demodulator that is 10 dB ±1 dB below the maximum allowed input of the FM demodulator. Record this level.

n) Adjust the RF level of the signal generator to provide RF power to the RF power meter 30 dB below the level noted in step m). This signal generator level shall be maintained throughout the rest of the measurement.

o) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the FM demodulator

p) Repeat steps q), r), s), and t) a sufficient number of times to collect 10 data samples.

q) Activate the PTT on the transmitter under test such that it transmits an ISP to request service.

r) After a short time, activate the modulation source to switch to a channel grant OSP signal. This should trigger the oscilloscope.

s) Record the time from the beginning of the OSP to the peak of the rising



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edge of the first symbol of the initial frame synchronization word on the assigned channel. The frame synchronization word is:

+3, +3, +3, +3, +3, -3, +3, +3, -3, -3, +3, +3, -3, -3, -3, -3, +3, -3, +3, -3, -3, -3, -3, -3

t) Deactivate the PTT on the transmitter to release the channel.

u) The encoder transmit time to key on a working channel is the average of the times recorded in step s).



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## 2.4 Methods of Measurement for Unit Characteristics

This section details the methods of measurement for general characteristics of communications equipment, including environmental testing. Unless otherwise noted, all parameters are measured during the time that the actual environment is present.

### 2.4.1 Power Supply Voltage Range

2.4.1.1 Definition

Power supply voltage range denotes the range of power supply voltages over which the equipment will operate with no more than a specified amount of degradation in overall performance. No internal adjustments of the equipment are permitted during this test.

2.4.1.2 Method of Measurement

a) Connect the equipment to a variable voltage power source. Adjust the voltage to the maximum voltage specified for the equipment.

b) Perform the desired tests, using the method of measurement specified in 2.1 and 2.2.

c) Repeat step b) with the power source adjusted for the minimum specified voltage for the equipment.

### 2.4.2 Temperature Range

2.4.2.1 Definition

Temperature range denotes the range of ambient temperature over which the transceiver will operate with no more than a specified maximum amount of degradation in overall performance. No internal adjustments of the transceiver are allowed during the temperature cycle.

2.4.2.2 Method of Measurement

a) Place the transceiver, installed in the case normally supplied, in a temperature chamber that has a rate of change in the temperature of ≤200 °C/hour.

b) With the power source to the transceiver removed, adjust the temperature of the chamber to the minimum temperature specified for the desired test. Maintain a constant temperature in the chamber without forced circulation of air directly on



--`,`,,`,`,`,`,,,`,,`,`,```,,,,-`-`,,`,,`,`,,`---

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the transceiver for a period of time that will allow the temperature in the transceiver to stabilize.

c) Apply the power source to the transceiver and allow 15 minutes, or the time specified by the manufacturer, for the unit to stabilize.

d) Perform the desired test, using the method of measurement specified in 2.1 and 2.2, over the duty cycle specified in 1.4.2.

e) Remove the power source from the transceiver.

f) Operating frequency error measurements should be made in ≤10 °C increments from the minimum to maximum temperatures.

g) With the power source to the transceiver removed, adjust the temperature of the chamber to the maximum temperature specified for the desired test. Maintain a constant temperature in the chamber without forced circulation of air directly on the transceiver for a period of time that will allow the temperature in the transceiver to stabilize.

h) Repeat steps c) and d).

### 2.4.3 High Humidity

2.4.3.2 Definition

High humidity denotes the relative humidity at which a transceiver will operate with no more than a specified maximum amount of degradation in overall performance. No internal adjustments of the transceiver are allowed during the humidity cycle.

2.4.3.2 Method of Measurement

a) Place the transceiver, installed in the case normally supplied, in a humidity chamber. This procedure shall be conducted in a manner that does not cause condensation.

b) With the power source to the transceiver removed, adjust the humidity of the chamber to the maximum humidity specified for the desired test. Maintain the constant specified temperature in the chamber without forced circulation of air directly on the transceiver.

c) After 8 hours in the chamber, apply the power source to the transceiver.

d) Perform the desired test, using the method of measurement specified in 2.1 and



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2.2, over the duty cycle specified in 1.4.2.

### 2.4.4 Vibration Stability

2.4.4.1 Definition

Vibration stability denotes the amount of mechanical vibration during and after which the equipment will operate with no more than a specified amount of degradation in overall performance, and without sustaining physical damage. No internal adjustments of the equipment are permitted during this test.

2.4.4.2 Method of Measurement

a) Mount the equipment under test to a vibration table, using the manufacturer's supplied mounting hardware, where applicable.

b) Adjust the vibration table for the amplitude and frequency range of vibration, and the frequency sweep rate specified for the equipment.

c) During the vibration perform the desired tests, using the method of measurements specified in 2.1 and 2.2.

### 2.4.5 Shock Stability

2.2.5.1 Definition

Shock stability denotes the amount of mechanical shock after which the equipment does not sustain physical damage, and no more than a specified amount of degradation in overall performance results. No internal adjustments of the equipment are permitted during this test.

2.2.4.2 Method of Measurement

a) Apply the specified shock to the equipment, either through a calibrated shock table, or a drop from a specified height, as the specification dictates.

b) After the specified number of shock cycles perform the desired tests, using the methods of measurement in 2.1 and 2.2.



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### 2.4.6 DC Supply Noise Susceptibility

2.4.6.1 Definition

Supply noise susceptibility denotes the level of power supply noise during which the equipment will operate with no more than a specified amount of degradation in overall performance. No internal adjustments of the equipment are permitted during this test.

2.4.6.2 Method of Measurement

a) Connect the equipment to a power supply that has the ability to superimpose a sinusoidal signal to the dc source.

b) Adjust the sinusoidal signal to the specified frequency and amplitude.

c) Perform the desired tests, using the method of measurement in 2.1 and 2.2.

### 2.4.7 Battery Life

2.4.7.1 Definition

The minimum battery life is the number of hours that the equipment will operate under the standard duty cycle on a single complement of batteries before the battery end point has been reached.

2.4.7.2 Method of Measurement

a) Adjust the equipment at the standard test voltage for rated carrier output power and rated audio output power.

b) Operate the equipment under the standard duty cycle, starting with a fully charged battery complement.

c) Operate the equipment until any of the following conditions are met:

   1) The manufacturer's specified discharge voltage is reached.

   2) The receiver reference sensitivity is degraded by 3 dB DFS.

   3) The transmitter RF output power is degraded by 6 dB DFS.

   4) The transmitter operating frequency error exceeds the allowable limit as stated in **[R2]**.



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d) The battery life is the time from the start of the test, until any of the conditions of step c) are met.

### 2.4.8 Dimensions

2.4.8.1 Definition

The dimensions are the physical size of the unit.

2.4.8.2 Method of Measurement

The equipment shall be measured together with all accessories that are required for operation and support during its intended use. The measurement shall give the overall physical size of the unit, which is the size of a box that is required to contain the unit. The following may be excluded from the measurement:

a) Antennas that protrude beyond the basic equipment.

b) Interconnection cables, such as power, microphone, antenna, etc.

c) Optional mounting hardware.

d) Optional convenience accessories, such as belt clips, holsters, etc.

For equipment that consists of more than one physical piece, each piece may be measured separately.

### 2.4.9 Weight

2.4.9.1 Definition

The weight is the physical weight of the unit.

2.4.9.2 Method of Measurement

The equipment shall be weighed together with all accessories required for operation and support during its intended use. The following may be excluded from the weight:

a) Optional mounting hardware.

b) Optional convenience accessories, such as belt clips, holsters, etc.

For equipment that consists of more than one physical piece, each piece may be



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weighed separately.

### 2.4.10 Other Environmental

2.4.10.1 Definition

Other environmental conditions, such as rain, salt fog, and dust, as well as other shock and vibration conditions are environmental requirements that are detailed in other documents.

2.4.10.2 Method of Measurement

a) Subject the equipment to the specified environments.

b) Perform the desired tests following subjection of the equipment to the specified environments.



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# Annex A (normative)

## Trunking Software Module Listings

The following software modules are documented in this annex:

```
bch.h
buildtsb.c
bch.c
crc.c
trellis.c
vector_operations.c
build_tsbk_and_print()
process_and_print_unconfirmed()
process_and_print_alternate_control.c
find_system_config()
find_fs()
read_tsbk()
data()
read_alternate_control()
read_unconf_data()
main()
crc.h
parm.h
trellis.h
vector_operations.h
```

```
/*******************************************************************************

     Name:  bch.h
   Author:  Al Wilson
     Date:  7/28/93
  History:  7/28/93  New

This module declares one function:
    bch_64_encode ( in, out )    encodes (64,16,23) primitive BCH code

*******************************************************************************/

#ifndef BCH_H

#define BCH_H

void bch_64_encode ( int, int * );
```



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```
#endif
```



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```
/*****************************************************************************

     Name:  buildtsb.c
   Author:  Mike Bright, Bob LoGalbo and Al Wilson
     Date:  5/5/96
  Version:  1.0

    This code will compose a trunking signalling message as specified by
    TSB102.AABB.  One file will be generated that can be transmitted by the
    CAI Lockdown Platform.

    The input format for this routine is specified by the separate read
    functions below.  This program accepts as input all data before
    FEC/Trellis/CRC encoding.  This code will error encode the input data
    and order the bits in the sequence specified by the CAI.  Virtually all
    input data is assumed e.g. the values of each bit of the FRAME SYNC,
    UNUSED fields, STATUS SYMBOLS, etc. must be specified.

    Upon calling the executable, the first two arguments respectively are
    <input_file> and <output_file>.  Just invoking the executable without
    arguments will cause the program to assume a default
    input file of "clear.dat" and stdout as the output file.

    Example input files follow.   Each input file must begin with two lines:
    OUTBOUND:  X
    MICROSLOTS PER SLOT:  Y
    where X is either 1 for OUTBOUND or 0 for INBOUND
    and   Y is any number (in hex) for the number of microslots that compose
    an inbound slot.

    Any line that contains multiple field values, will have the first field
    value ignored and the rest of the field values read in (all I/O is
    assumed to be in hex.)

    Example line->  NID  : 2935  NAC = 411; DUID = 5 --> Only the value of 411
    and 5 will be read in and the value of 2935 will be ignored.

    This routine is data driven i.e. it reads until the input file is empty
    and all formats are keyed off of the DUID.   The only valid DUID's
    this module will accept is 0x7 and 0xC.  All of the pertinent data
    following the "Data Block:" section will be read in, and drives the
    formatting process.

OUTBOUND:  1
MICROSLOTS PER SLOT:  5
Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 293C       NAC = 293; DUID = C
SS      : 1
Unconfirmed Header Block:
OCTET 0 : 35         Unused = 0; ANb = 0; IbO = 1; Format = 15
OCTET 1 : c0         Unused = 3; SAP = 00
MFID    : 00
LLID    : 00 0001
OCTET 6 : 82         FMF = 1; Blocks to Follow = 02
OCTET 7 : 08         Unused = 0; Pad = 08
Reserved: 00
OCTET 9 : 02         Unused = 0; Offset = 02
Data Block:
```



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```
00 01 02 03 04 05 06 07 08 09 0a 0b 00 00 00 00 00 00 00 00
#
Packet Data Unit #2:
FS      : 5575 f5ff 77ff
NID     : 293C       NAC = 293; DUID = C
SS      : 1
Unconfirmed Header Block:
OCTET 0 : 35         Unused = 0; ANb = 0; IbO = 1; Format = 15
OCTET 1 : c0         Unused = 3; SAP = 00
MFID    : 00
LLID    : 00 0001
OCTET 6 : 82         FMF = 1; Blocks to Follow = 02
OCTET 7 : 08         Unused = 0; Pad = 08
Reserved: 00
OCTET 9 : 02         Unused = 0; Offset = 02
Data Block:
0c 0d 0e 0f 10 12 13 14 15 16 17 18 00 00 00 00 00 00 00 00
#
-------------------------------------------------------------
OUTBOUND:  1
MICROSLOTS PER SLOT:  5
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 293C       NAC = 293; DUID = C
SS      : 1
Multiple Trunked Block OSP:
OCTET 0 : 37         Unused = 0; ANb = 0; IbO = 1; Format = 17
OCTET 1 : c0         Unused = 3; SAP = 00
MFID    : 00
LLID    : 00 0001
OCTET 6 : 83         FMF = 1; Blocks to Follow = 02
OCTET 7 : 0b         Unused = 0; Opcode = 08
OCTET 8 : 00         Trunked Message 1 = 00
OCTET 9 : 00         Trunked Message 2 = 02
Data Block:
00 01 02 03 04 05 06 07 08 09 0a 0b 00 00 00 00 00 00 00 00
#
Control Channel Packet Data Unit #2:
FS      : 5575 f5ff 77ff
NID     : 293C       NAC = 293; DUID = C
SS      : 1
Multiple Trunked Block OSP:
OCTET 0 : 37         Unused = 0; ANb = 0; IbO = 1; Format = 17
OCTET 1 : c0         Unused = 3; SAP = 00
MFID    : 00
LLID    : 00 0001
OCTET 6 : 83         FMF = 1; Blocks to Follow = 02
OCTET 7 : 0b         Unused = 0; Opcode = 08
OCTET 8 : 00         Trunked Message 1 = 00
OCTET 9 : 00         Trunked Message 2 = 02
Data Block:
0c 0d 0e 0f 10 12 13 14 15 16 17 18 00 00 00 00 00 00 00 00
#
-------------------------------------------------------------
OUTBOUND:  0
MICROSLOTS PER SLOT:  5
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 293C       NAC = 293; DUID = 7
```



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```
SS       : 1
TSBK #1:
OCTET 0 : 15          LB = 0; P = 0; Opcode = 35
MFID    : df
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 01
OCTET 6 : 82
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 00
TSBK #2:
OCTET 0 : 15          LB = 0; P = 0; Opcode = 15
MFID    : c0
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 02
OCTET 6 : 00
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 00
TSBK #3:
OCTET 0 : 15          LB = 1; P = 0; Opcode = 01
MFID    : 23
OCTET 2 : 45
OCTET 3 : 67
OCTET 4 : 89
OCTET 5 : ab
OCTET 6 : cd
OCTET 7 : ef
OCTET 8 : 00
OCTET 9 : 00
Control Channel Packet Data Unit #1:
FS      : 5575 f5ff 77ff
NID     : 293C        NAC = 293; DUID = 7
SS      : 1
TSBK #1:
OCTET 0 : 15          LB = 0; P = 0; Opcode = 35
MFID    : df
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 01
OCTET 6 : 82
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 00
TSBK #2:
OCTET 0 : 15          LB = 0; P = 0; Opcode = 15
MFID    : c0
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 02
OCTET 6 : 00
OCTET 7 : 00
OCTET 8 : 00
```



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```
OCTET 9 : 00
TSBK #3:
OCTET 0 : 15         LB = 1; P = 0; Opcode = 01
MFID    : 23
OCTET 2 : 45
OCTET 3 : 67
OCTET 4 : 89
OCTET 5 : ab
OCTET 6 : cd
OCTET 7 : ef
OCTET 8 : 00
OCTET 9 : 00

    The output format is either 18 or 36 hex characters
    per line.   The left most bit is the first bit to be transmitted.
    All frame syncs will appear in the left most position of each line.

******************************************************************************/
#define IDLE_SS 0X3  /* Idle status symbol value */
int ss_count = 0;    /* Global variable that counts the number of status
                        symbols generated over the entire output file
                        generation.*/
```



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```
/***************************************************************************

     Name:  bch.c
   Author:  Al Wilson
     Date:  7/28/93
  History:  7/28/93  New

This module contains one functions:
    bch_64_encode ( in, out )    encodes (64,16,23) primitive BCH code
The functions takes a 16 bit integer as an argument, and returns four 16-bit
values for the corresponding code word.

***************************************************************************/

#include "bch.h"
void bch_64_encode( int in_word, int * code_word_out )
{
static int matrix[16][4] = {0x8000, 0xcd93, 0x0bdd, 0x3b2a,
                            0x4000, 0xab5a, 0x8e33, 0xa6be,
                            0x2000, 0x983e, 0x4cc4, 0xe874,
                            0x1000, 0x4c1f, 0x2662, 0x743a,
                            0x0800, 0xeb9c, 0x98ec, 0x0136,
                            0x0400, 0xb85d, 0x47ab, 0x3bb0,
                            0x0200, 0x5c2e, 0xa3d5, 0x9dd8,
                            0x0100, 0x2e17, 0x51ea, 0xceec,
                            0x0080, 0x170b, 0xa8f5, 0x6776,
                            0x0040, 0xc616, 0xdfa7, 0x8890,
                            0x0020, 0x630b, 0x6fd3, 0xc448,
                            0x0010, 0x3185, 0xb7e9, 0xe224,
                            0x0008, 0x18c2, 0xdbf4, 0xf112,
                            0x0004, 0xc1f2, 0x6627, 0x43a2,
                            0x0002, 0xad6a, 0x38ce, 0x9afb,
                            0x0001, 0x9b26, 0x17ba, 0x7657};

static int code_word_mask[16] = {0x8000,
                                 0x4000,
                                 0x2000,
                                 0x1000,
                                 0x0800,
                                 0x0400,
                                 0x0200,
                                 0x0100,
                                 0x0080,
                                 0x0040,
                                 0x0020,
                                 0x0010,
                                 0x0008,
                                 0x0004,
                                 0x0002,
                                 0x0001};

    int temp_word;
    char i, j;

    for(j=0;j<4;j++)
    {
      code_word_out[j] = 0;
      for(i=0;i<16;i++)
      {
```



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```
        temp_word = in_word & code_word_mask[i];
        if(temp_word >= 1)
           code_word_out[j] = code_word_out[j] ^ matrix[i][j];
      }
    }

}
```



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```
/**************************************************************************

     Name:  crc.c
   Author:  Al Wilson
     Date:  8/4/93
  History:  8/4/93  New

This module contains three functions:
    crc_ccitt ( pointer )   encodes the header parity check
    crc_9 ( num, pointer )  encodes the confirmed data block parity check
    crc_32 ( length, pointer )      encodes the data parity check
The pointer points to a list of integers.  The 32 bit pointer is a variable
length list.  The first two functions return a 16 bit and a 9 bit result
respectively.  The last function returns a 32 bit long integer result.

The arguments must follow the following rules.

    crc_ccitt  pointer  --  must point to an array of 10 octets

    crc_9      num      --  is a 7-bit serial number for the data block
               pointer  --  must point to an array of 16 octets

    crc_32     length   --  indicates the length of the array, 1..512
               pointer  --  must point to an array of (length) octets

**************************************************************************/

#include "crc.h"

#define G_16  ((1 << 12) | (1 << 5) | 1)
#define G_9   ((1 << 6) | (1 << 4) | (1 << 3) | 1)
#define G_32  0x04c11db7

int crc_ccitt ( int * ptr )

{

    int temp;
    int i, j;

    temp = 0;
    for ( i=0; i<10; i++ )
    {
      for ( j=7; j>=0; j-- )
      {
        if ( ( (temp >> 15) ^ ((*(ptr+i)) >> j) ) & 1 )
               temp = (temp << 1) ^ G_16;
        else   temp =  temp << 1;
      }
    }
    temp = ( temp & 0xffff ) ^ 0xffff;
    return ( temp );

}

int crc_9 ( int num, int * ptr )

{
```



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```
    int temp;
    int i, j;

    temp = 0;
    for ( j=6; j>=0; j-- )
    {
      if ( ( (temp >> 8) ^ (num >> j) ) & 1 )
             temp = (temp << 1) ^ G_9;
      else   temp =  temp << 1;
    }
    for ( i=0; i<16; i++ )
    {
      for ( j=7; j>=0; j-- )
      {
        if ( ( (temp >> 8) ^ ((*(ptr+i)) >> j) ) & 1 )
               temp = (temp << 1) ^ G_9;
        else   temp =  temp << 1;
      }
    }
    temp = ( temp & 0x1ff ) ^ 0x1ff;
    return ( temp );

}

long int crc_32 ( int length, int * ptr )

{

    long int temp;
    int i, j;

    temp = 0;
    for ( i=0; i<length; i++ )
    {
      for ( j=7; j>=0; j-- )
      {
        if ( ( (temp >> 31) ^ ((*(ptr+i)) >> j) ) & 1 )
               temp = ( temp << 1 ) ^ G_32;
        else   temp =   temp << 1;
      }
    }
    temp =   temp ^ 0xffffffff;
    return ( temp );

}
```



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```
/*************************************************************************

     Name:  trellis.c
   Author:  Al Wilson
     Date:  8/5/93
  History:  8/5/93  New

This module defines two functions:
    trellis_3_4_encode ( in, out )    encodes the rate 3/4 trellis code
    trellis_1_2_encode ( in, out )    encodes the rate 1/2 trellis code
The input and output arguments are pointers a integer vectors.  The input
arguments must point to octets while the output arguments point to an array
of 14 integers with 14 bits in each (196 bits in total).

*************************************************************************/
#include <stdio.h>
#include "trellis.h"
#include "vectorop.h"

static int sigIndx_1_2[4][4] = {
 0, 15, 12,  3,
 4, 11,  8,  7,
13,  2,  1, 14,
 9,  6,  5, 10};

static int sigIndx_3_4[8][8] = {
 0,  8,  4, 12,  2, 10,  6, 14,
 4, 12,  2, 10,  6, 14,  0,  8,
 1,  9,  5, 13,  3, 11,  7, 15,
 5, 13,  3, 11,  7, 15,  1,  9,
 3, 11,  7, 15,  1,  9,  5, 13,
 7, 15,  1,  9,  5, 13,  3, 11,
 2, 10,  6, 14,  0,  8,  4, 12,
 6, 14,  0,  8,  4, 12,  2, 10};

static int signalP[16][2] = {
 0, 2,  2, 2,
 1, 3,  3, 3,
 3, 2,  1, 2,
 2, 3,  0, 3,
 3, 1,  1, 1,
 2, 0,  0, 0,
 0, 1,  2, 1,
 1, 0,  3, 0};

static int intlvRule[98] = {
  0,  1,   8,  9,  16, 17,  24, 25,  32, 33,  40, 41,
             48, 49,  56, 57,  64, 65,  72, 73,  80, 81,  88, 89,  96, 97,
  2,  3,  10, 11,  18, 19,  26, 27,  34, 35,  42, 43,
             50, 51,  58, 59,  66, 67,  74, 75,  82, 83,  90, 91,
  4,  5,  12, 13,  20, 21,  28, 29,  36, 37,  44, 45,
             52, 53,  60, 61,  68, 69,  76, 77,  84, 85,  92, 93,
  6,  7,  14, 15,  22, 23,  30, 31,  38, 39,  46, 47,
             54, 55,  62, 63,  70, 71,  78, 79,  86, 87,  94, 95 };

void trellis_3_4_encode(int * inBlock, int * outBlock)
{
    int i, k;
    int state, sig;
```



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```
    int tri_bits[49];
    int di_bits[98];

    for(i=0;i<49;i++)
       tri_bits[i]=0;
    for(i=0;i<98;i++)
       di_bits[i]=0;


    for ( k=0; k<18; k++ )  tri_bits[k] = inBlock[k];
    tri_bits[18] = 0;  /* This will become the null tri-bit at the end. */
    for ( k=0; k<49; k++ )  shift_vector_right( 49-k, 8, 5, &tri_bits[k]);
    state = 0;
    for ( k=0; k<49; k++)
    {
      sig = sigIndx_3_4[state][ tri_bits[k] ];
      di_bits[2*k    ] = signalP[sig][0];
      di_bits[2*k + 1] = signalP[sig][1];
      state = tri_bits[k];
    }
    for ( k=0; k<14; k++ )
    {
      sig = 0;
      for ( i=0; i<7; i++ )
      {
        sig = (sig << 2) | di_bits[intlvRule[7*k + i]];
      }
      *(outBlock + k) = sig;
    }
}

void trellis_1_2_encode(int * inBlock, int * outBlock)
{
    int i, k;
    int state, sig;
    int di_bits_in[49];
    int di_bits[98];

    for(i=0;i<49;i++)
       di_bits_in[i]=0;
    for(i=0;i<98;i++)
       di_bits[i]=0;
    for ( k=0; k<12; k++ )  di_bits_in[k] = inBlock[k];
    di_bits_in[12] = 0;  /* This will become the null di-bit at the end. */
    for ( k=0; k<49; k++ )  shift_vector_right( 49-k, 8, 6, &di_bits_in[k]);
    state = 0;
    for ( k=0; k<49; k++)
    {
      sig = sigIndx_1_2[state][ di_bits_in[k] ];
      di_bits[2*k    ] = signalP[sig][0];
      di_bits[2*k + 1] = signalP[sig][1];
      state = di_bits_in[k];
    }

    for ( k=0; k<14; k++ )
    {
      sig = 0;
      for ( i=0; i<7; i++ )
      {
```



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```
            sig = (sig << 2) | di_bits[intlvRule[7*k + i]];
        }
        *(outBlock + k) = sig;
    }
}
```



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```
/******************************************************************************

     Name:  vector_operations.c
   Author:  Al Wilson
     Date:  8/3/93
  History:  8/3/93  New

This module defines two functions for operations on vectors:
    shift_vector_right ( int length, int element_length, int shift, int * ptr )
    extract_dibit ( int length, int element_length, int * ptr )

The arguments to the two functions are as follows:
    length         -- indicates the number of elements in the vector
    element_length -- indicates the number of bits in each element
    shift          -- indicates the number of bits to shift [ to the right ]
    ptr            -- pointer to the first element of the vector

The shift_vector_right function has the following restrictions:
    length         -- must be >= 1
    element_length -- must be 1..16
    shift          -- must be < element_length
The function operates by shifting each element to the right, starting with
the first element pointed to by the pointer.  It takes the LSBs that shift
out of the element, and shifts them into the next element, starting at the
MSB indicated by the element_length argument.  The bits shifted out of the
last element in the vector are discarded.

The extract_dibit function uses the shift_vector_right function to extract
the 2 MSBs of the first vector element (pointed to by the ptr argument).  This
is done by shifting to the right (element_length - 2) bits.  The result in the
first element is simply the 2 MSBs, in the LSB positions.  This is then
returned as the extracted dibit.  The vector is then left shifted by moving
each element from position i+1 to position i.

To prevent the last element in the vector from loosing 2 bits, an additional
element is assumed to exist in the vector beyond the indicated length.
Consequently, the actually allocated length of the vector must be at least
(length + 1).

******************************************************************************/

#include "vectorop.h"

void shift_vector_right(int vector_length,  /* should be >= 1             */
                        int element_length, /* should be 1..16            */
                        int shift,          /* should be < element_length */
                        int * pointer)

{

    int i, temp;

    for ( i=vector_length-1;  i>=0;  i-- )
    {
        if ( i > 0 ) temp = *(pointer+i-1);
        else         temp = 0;
        temp &= (1 << shift) - 1;
        *(pointer+i) = (unsigned int)(*(pointer+i)) >> shift;
        *(pointer+i) = (*(pointer+i)) | (temp << (element_length - shift));
```



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```
    }

}

int extract_dibit ( int vector_length,   /* should be >= 1   */
                    int element_length,  /* should be 1..16  */
                    int * pointer )

{

    int temp, i;

    *(pointer+vector_length) = 0;  /* vector should have one extra element */
    shift_vector_right ( vector_length+1, element_length,
                         element_length-2, pointer );
    temp = *pointer;
    for ( i=0;  i<vector_length;  i++ )
        *(pointer + i) = *(pointer + i + 1);
    *(pointer+vector_length) = 0;  /* clean up the residue */
    return ( temp & 0x3 );

}
```



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```
/*****************************************************************************

     Name:  build_tsbk_and_print()
   Author:  Bob LoGalbo & Al Wilson
     Date:  4/15/96
  History:  8/5/93  New
            9/5/93  Fixed exception for zero data blocks.

This function accepts a structure with all of the necessary values to create
TSBK data packets consisting of the frame sync, nid, etc.  All of the input
values are raw data before error correction.  CRC generation, trellis encoding,
BCH parity generation is done by this module (through subroutine calls.)

Note that any extraneous bits read in and pushed into the structure elements
will be trimmed back if too large to fit into a given field (e.g. only 48
bits allowed for sync, 12 bits allowed for NID, etc.)

The program then generates one complete TSBK with all of the appropriate
signalling.  The output is formatted in hexadecimal, and is ready to be
presented to the lockdown platform.


*****************************************************************************/

#include "bch.h"
#include "crc.h"
#include "trellis.h"
#include <stdio.h>
#include "vectorop.h"
#include "parm.h"    /* This include file contains the structure whose elements
                        compose the various components of CAI frames.       */


#define  DUID_TSBK          0x7    /* Data Unit ID for Data Packet */

int build_tsbk_and_print(struct parm *data,FILE *out)
{
    int blocks_to_follow;
    long int data_crc;
    int data_length, header_crc;
    int data_octets[528];
    int sarq_crc[34];
    int data_block[15];   /* enough for 1 block + 1 extra                   */
    int header_block[12];
    int sarq_block[18];   /* 18 octets with the ser. no. + CRC9             */
    int data_output[150][6];    /* 150microslots, 6 ints of 12 bits per slot*/
    int error_state, i, j, k;
    int fs[4];            /* Frame Sync                                     */
    int nid[5];           /* Network ID code word                           */
    int microslot, word;
    int total_di_bits;    /* The number of dibits, not counting busy bits   */
    int total_microslots; /* The number of status symbols.                  */
    int data_block_di_bit;
    int data_block_number;
    int status_for_this_slot;


    /* data_length      = 16 * blocks_to_follow - 4 - pad_octet_count; */
    /* Initialize data_octets. */
```



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```
    for(i=0;i<528;i++)
        data_octets[i]=0;

    for(i=0;i<15;i++)
        data_block[i]=0;

    /* Do the Frame Sync */
    for ( i=0;  i<3;   i++ )  fs[i] = (data->fs[i] & 0xFFFF);
    fs[3] = 0;

    /* Do the Status Symbols */
    data->status &= 0x3;

    /* Do the Network ID */
    for ( i=0; i<5; i++ )  nid[i] = 0;
    bch_64_encode ( ((data->nac << 4) & 0xFFF0) |  (data->duid & 0xf), nid );


        /* Do the header block */
        header_block[0] = ((data->lb[0] & 0x1) << 7)|((data->p[0]&0x1)<<6)
                         | (data->opcode[0] & 0x3f);
        header_block[1] =   data->mfid[0]       & 0xff;
        header_block[2] =   data->octet2[0]     & 0xff;
        header_block[3] =   data->octet3[0]     & 0xff;
        header_block[4] =   data->octet4[0]     & 0xff;
        header_block[5] =   data->octet5[0]     & 0xff;
        header_block[6] =   data->octet6[0]     & 0xff;
        header_block[7] =   data->octet7[0]     & 0xff;
        header_block[8] =   data->octet8[0]     & 0xff;
        header_block[9] =   data->octet9[0]     & 0xff;
        header_crc = crc_ccitt ( header_block );
        header_block[10] = 0xff & (header_crc >> 8);
        header_block[11] = 0xff &  header_crc;
        trellis_1_2_encode ( header_block, data_block );
        k=0;
        for(i=1; i<data->block_count; i++)
        {
           header_block[0] = ((data->lb[i] & 0x1) << 7)
                 | ((data->p[i] & 0x1) << 6) | (data->opcode[i] & 0x3f);
           header_block[1] =   data->mfid[i]       & 0xff;
           header_block[2] =   data->octet2[i]     & 0xff;
           header_block[3] =   data->octet3[i]     & 0xff;
           header_block[4] =   data->octet4[i]     & 0xff;
           header_block[5] =   data->octet5[i]     & 0xff;
           header_block[6] =   data->octet6[i]     & 0xff;
           header_block[7] =   data->octet7[i]     & 0xff;
           header_block[8] =   data->octet8[i]     & 0xff;
           header_block[9] =   data->octet9[i]     & 0xff;
           header_crc = crc_ccitt ( header_block );
           header_block[10] = 0xff & (header_crc >> 8);
           header_block[11] = 0xff &  header_crc;
           for ( j=0;  j<12;  k++,j++ )
                 data_octets[k] =  header_block[j];
        }


        for (i=0;i<150;i++ )for(j=0;j<6;j++) data_output[i][j] = 0;
/*        for(i=0; i < 12 ;i++)
           printf("h_b[%d] = %02x\n",i,header_block[i]);*/
```



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```
/* Get data ready to turn into blocks. */

data_block_number = 1;

/* There are 24 frame sync dibits
             32 NID dibits
             98 dibits for each block (add 1 for header block)
*/
/* Total di_bits = fs + nid + header + btf(non term) + term
            (btf should include the enhanced block, if it exists. */
data_block_di_bit = 98;             /* number of dibits in array */
total_di_bits = 24 + 32 + (98 * data->block_count);
total_microslots = (total_di_bits + 34)/35;
total_di_bits += total_di_bits/35;  /* Allow for embedded busy bits */
microslot = 0;  word = 0;
for ( i=0;  i<36*total_microslots;  i++ )
{
    data_output[microslot][word] = data_output[microslot][word] << 2;
    if ( i%36 == 35 )               /* Status Symbol    */
    {
        if((ss_count%data->microslots_per_slot == 0)
        && (data->outbound == 1))
            status_for_this_slot = IDLE_SS;
        else
            status_for_this_slot = data->status;
        ss_count++;
        data_output[microslot][word] |= status_for_this_slot;
    }
    else if ( i < 24 )              /* Frame Sync       */
    {
        data_output[microslot][word] |= extract_dibit(3,16,fs);
    }
    else if ( i < 57 )              /* Network ID       */
    {
        data_output[microslot][word] |= extract_dibit(4,16,nid);
    }
    else if ( i < total_di_bits )   /* Data Block Unpacking */
    {
        data_output[microslot][word] |= extract_dibit(14,14,data_block);
        data_block_di_bit--;
    }
    else                            /* Trailing nulls   */
    {
        data_output[microslot][word] |= 0;
    }
    /* Data blocks (non-header) */
    if ( data_block_di_bit <= 0 && data_block_number < data->block_count)
    {

        trellis_1_2_encode ( &data_octets[12*(data_block_number-1)],
                             data_block );

        data_block_di_bit = 98;
        data_block_number++;
    }
    if ( i%6 == 5 )  word++;
    if ( word == 6 )  {  microslot++;  word = 0; }
}
for ( i=0; i<total_microslots; i++ )
```



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```
        {
             for ( j=0; j<6; j++ )
                fprintf(out, "%03x", data_output[i][j]);
             if ( i % 2 == 1)
                fprintf(out, "\n");
        }
        if ( (i-1) % 2 == 0)
           fprintf(out, "\n");
   return(0);
}
```



--`,`,,`,`,`,`,,,`,,`,`,````,,,,-`-`,,`,,`,`,,`---

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```
/*****************************************************************************

     Name:  process_and_print_unconfirmed()
   Author:  Bob LoGalbo & Al Wilson
     Date:  4/15/96
  History:  8/5/93  New
            9/5/93  Fixed exception for zero data blocks.

This function accepts a structure with all of the necessary values to create
unconfirmed data packets consisting of the frame sync, nid, etc.  All of the
input values are raw data before error correction.  CRC generation, trellis
encoding, BCH parity generation is done by this module
(through calls to various subroutines).

Note that any extraneous bits read in and pushed into the structure elements
will be trimmed back if too large to fit into a given field (e.g. only 48 bits
allowed for sync, 12 bits allowed for NID, etc.)

The program then generates one complete unconfirmed control packet with all
of the appropriate signalling.  The output is formatted in hexadecimal, and is
ready to be presented to the lockdown platform.


*****************************************************************************/

#include "bch.h"
#include "crc.h"
#include "trellis.h"
#include <stdio.h>
#include "vectorop.h"
#include "parm.h"/* This include file contains the structure whose
                    elements compose the various components of CAI frames.*/


#define  DUID_DATA_UNCONF          0xc    /* Data Unit ID for Data Packet */

int process_and_print_unconfirmed(FILE *out,struct parm *data)
{
    int blocks_to_follow;
    long int data_crc;
    int data_length, header_crc;
    int data_octets[528];
    int sarq_crc[34];
    int data_block[15];   /* enough for 1 block + 1 extra                 */
    int header_block[12];
    int sarq_block[18];   /* 18 octets with the ser. no. + CRC9           */
    int data_output[150][6];   /* 150microslots, 6 ints of 12 bits per slot*/
    int error_state, i, j, k;
    int fs[4];            /* Frame Sync                                   */
    int nid[5];           /* Network ID code word                         */
    int microslot, word;
    int total_di_bits;    /* The number of dibits, not counting busy bits   */
    int total_microslots; /* The number of status symbols.                */
    int data_block_di_bit;
    int data_block_number;
    int status_for_this_slot;


        /* data_length      = 16 * blocks_to_follow - 4 - pad_octet_count; */
```



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```
    /* Initialize data_octets. */
    for(i=0;i<528;i++)
        data_octets[i]=0;

    for(i=0;i<15;i++)
        data_block[i]=0;

/* Do the Frame Sync */
for ( i=0;  i<3;   i++ )  fs[i] = (data->fs[i] & 0xFFFF);
fs[3] = 0;

/* Do the Status Symbols */
data->status &= 0x3;

/* Do the Network ID */
for ( i=0; i<5; i++ )  nid[i] = 0;
bch_64_encode ( ((data->nac << 4) & 0xFFF0) |  (data->duid & 0xf), nid );


    /* Do the header block */
    header_block[0] = ((data->unused0 & 0x1) << 7) | ((data->anb & 0x1) << 6)
                    | ((data->ibo & 0x1) << 5) | (data->format & 0x1f);
    header_block[1] = ((data->unused1  & 0x3) << 6) |  (data->sap & 0x3f);
    header_block[2] =   (data->mfid[0]  & 0xff);
    header_block[3] =   (data->dest[0]  & 0xFF);
    header_block[4] = ((data->dest[1]  & 0xFF00)>>8);
    header_block[5] =   (data->dest[1]  & 0xFF);
    header_block[6] = ((data->fmf      & 0x1) << 7) |   (data->btf & 0x7f);
    header_block[7] =   ((data->unused7  & 0x7)  << 5) |(data->pad & 0x1f);
    header_block[8] =   (data->reserved[0] & 0xff);
    header_block[9] = ((data->unused9 & 0x3) << 6) |   (data->offset & 0x3f);
    header_crc = crc_ccitt ( header_block );
    header_block[10] = 0xff & (header_crc >> 8);
    header_block[11] = 0xff &  header_crc;
    trellis_1_2_encode ( header_block, data_block );
    i=0;
    if(data->sap == 0x1f)  /* If enhanced addressing push the LLID, SAP ID,
                              etc. into data array */
    {

         header_block[0] =  0x15; /* The format for the intermediate file
                                     does not allow the user to control
                                     the bits in the first octet of the
                                     second header.  */
         header_block[1] = ((data->eh_unused  & 0x3) << 6)
                         |  (data->eh_2nd_sap & 0x3f);
         header_block[2] =   data->mfid[0]     & 0xff;
         header_block[3] =   data->source[0]  & 0xFF;
         header_block[4] = ( data->source[1]  & 0xFF00)>>8;
         header_block[5] =   data->source[1]  & 0xFF;
         header_block[6] = ( data->eh_reserved[0]  & 0xFF00)>>8;
         header_block[7] =   data->eh_reserved[0]  & 0xFF;
         header_block[8] = ( data->eh_reserved[1]  & 0xFF00)>>8;
         header_block[9] =   data->eh_reserved[1]  & 0xFF;
         header_crc = crc_ccitt ( header_block );
         header_block[10] = 0xff & (header_crc >> 8);
         header_block[11] = 0xff &  header_crc;
         for ( j=0;  j<12;  i++,j++ )
             data_octets[i] =  header_block[j];
```



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```
        }
        for ( j=0;  j<data->nbytes;  i++,j++ )
        {
            data_octets[i]   = data->data[j] & 0xff;
/*            printf("data_octet[%d] = %02x\n",i,data_octets[i]);*/
        }
        if(data->sap == 0x1f)
             data->nbytes+=12;
        if(i%12 > 8)/* i = number of data octets that will be packed
                                 and framed up */
            blocks_to_follow = i/12+2;
        else                                    /* data_in_last_block <=12 */
            blocks_to_follow = i/12+1;
        for ( i=0; i<150; i++ )  for ( j=0;  j<6;  j++ ) data_output[i][j] = 0;
/*        for(i=0; i < 12 ;i++)
           printf("h_b[%d] = %02x\n",i,header_block[i]);*/
        /* Get data ready to turn into blocks. */
        if ( data->nbytes > 0 )
        {
           data_crc = crc_32 ( data->nbytes, data_octets );
           for ( i=data->nbytes+3; i>=data->nbytes; i--)
           {
                data_octets[i] = 0xff & data_crc;
                /*printf("data_crc[%d] = %02x\n",i,data_octets[i]);*/
                data_crc = data_crc >> 8;
           }
        }
        data_block_number = 0;

        /* There are 24 frame sync dibits
                     32 NID dibits
                     98 dibits for each block (add 1 for header block)
        */
        /* Total di_bits = fs + nid + header + btf(non term) + term
                    (btf should include the enhanced block, if it exists. */
        data_block_di_bit = 98;             /* number of dibits in array */
        total_di_bits = 24 + 32 + 98 * (1 + blocks_to_follow);
        total_microslots = (total_di_bits + 34)/35;
        total_di_bits += total_di_bits/35;  /* Allow for embedded busy bits */
        microslot = 0;  word = 0;

        for ( i=0;  i<36*total_microslots;  i++ )
        {
            data_output[microslot][word] = data_output[microslot][word] << 2;
            if ( i%36 == 35 )               /* Status Symbol    */
            {
                if((ss_count%data->microslots_per_slot == 0)
                  && (data->outbound == 1))
                    status_for_this_slot = IDLE_SS;
                else
                    status_for_this_slot = data->status;
                ss_count++;
                data_output[microslot][word] |= status_for_this_slot;
            }
            else if ( i < 24 )              /* Frame Sync       */
            {
                data_output[microslot][word] |= extract_dibit(3,16,fs);
            }
            else if ( i < 57 )              /* Network ID       */
```



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```
            {
                data_output[microslot][word] |= extract_dibit(4,16,nid);
            }
            else if ( i < total_di_bits )    /* Data Block Unpacking */
            {
                data_output[microslot][word] |= extract_dibit(14,14,data_block);
                data_block_di_bit--;
            }
            else                             /* Trailing nulls   */
            {
                data_output[microslot][word] |= 0;
            }
            if ( data_block_di_bit <= 0 && data_block_number < blocks_to_follow)
            {
                trellis_1_2_encode ( &data_octets[12*data_block_number],
                                     data_block );
                data_block_di_bit = 98;
                data_block_number++;
            }
            if ( i%6 == 5 )  word++;
            if ( word == 6 )  {  microslot++;  word = 0; }
        }
        for ( i=0; i<total_microslots; i++ )
        {
             for ( j=0; j<6; j++ )
                fprintf(out, "%03x", data_output[i][j]);
             if ( i % 2 == 1)
                fprintf(out, "\n");
        }
        if ( (i-1) % 2 == 0)
           fprintf(out, "\n");

    return(0);
}
```



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```
/*****************************************************************************

     Name:  process_and_print_alternate_control.c
   Author:  Bob LoGalbo & Al Wilson
     Date:  4/15/96
  History:  8/5/93  New
            9/5/93  Fixed exception for zero data blocks.

This function accepts a structure with all of the necessary values to create
alternate control data packets consisting of the frame sync, nid, etc.  All of
the input values are raw data before error correction.  CRC generation, trellis
encoding, BCH parity generation is done by this module (through calls to various
subroutines).

Note that any extraneous bits read in and pushed into the structure elements
will be trimmed back if too large to fit into a given field (e.g. only 48 bits
allowed for sync, 12 bits allowed for NID, etc.)

The program then generates one complete alternate control data packet with all
of the appropriate signalling.  The output is formatted in hexadecimal, and is
ready to be presented to the lockdown platform.


*****************************************************************************/

#include "bch.h"
#include "crc.h"
#include "trellis.h"
#include <stdio.h>
#include "vectorop.h"
#include "parm.h"/* This include file contains the structure whose elements
                    compose the various components of CAI frames.        */


#define  DUID_DATA_UNCONF          0xc    /* Data Unit ID for Data Packet */

int process_and_print_alternate_control(FILE *out,struct parm *data)
{
    int blocks_to_follow;
    long int data_crc;
    int data_length, header_crc;
    int data_octets[528];
    int sarq_crc[34];
    int data_block[15];   /* enough for 1 block + 1 extra                   */
    int header_block[12];
    int sarq_block[18];   /* 18 octets with the ser. no. + CRC9             */
    int data_output[150][6];  /* 150microslots, 6 ints of 12 bits per slot  */
    int error_state, i, j, k;
    int fs[4];            /* Frame Sync                                     */
    int nid[5];           /* Network ID code word                           */
    int microslot, word;
    int total_di_bits;    /* The number of dibits, not counting busy bits   */
    int total_microslots; /* The number of status symbols.                  */
    int data_block_di_bit;
    int data_block_number;
    int status_for_this_slot;
```



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```
    /* data_length      = 16 * blocks_to_follow - 4 - pad_octet_count; */
    /* Initialize data_octets. */
    for(i=0;i<528;i++)
        data_octets[i]=0;

    for(i=0;i<15;i++)
        data_block[i]=0;

/* Do the Frame Sync */
for ( i=0;  i<3;   i++ )  fs[i] = (data->fs[i] & 0xFFFF);
fs[3] = 0;

/* Do the Status Symbols */
data->status &= 0x3;

/* Do the Network ID */
for ( i=0; i<5; i++ )  nid[i] = 0;
bch_64_encode ( ((data->nac << 4) & 0xFFF0) |  (data->duid & 0xf), nid );


    /* Do the header block */
    header_block[0] = ((data->unused0 & 0x1) << 7)|((data->anb&0x1)<<6)
                   | ((data->ibo & 0x1) << 5) | data->format & 0x1f;
    header_block[1] = ((data->unused1  & 0x3) << 6) |(data->sap & 0x3f);
    header_block[2] =   data->mfid[0]  & 0xff;
    header_block[3] =   data->dest[0]  & 0xFF;
    header_block[4] = ( data->dest[1]  & 0xFF00)>>8;
    header_block[5] =   data->dest[1]  & 0xFF;
    header_block[6] = ((data->fmf      & 0x1) << 7)|data->btf & 0x7f;
    header_block[7] = ((data->unused7  & 0x3)<<6)|data->opcode[0]&0x3f;
    header_block[8] =   data->tm1 & 0xff;
    header_block[9] =   data->tm2 & 0xff;
    header_crc = crc_ccitt ( header_block );
    header_block[10] = 0xff & (header_crc >> 8);
    header_block[11] = 0xff &  header_crc;
    trellis_1_2_encode ( header_block, data_block );
    i=0;
    if(data->sap == 0x1f)  /* If enhanced addressing push the LLID,
                              SAP ID, etc. into data array */
    {

         header_block[0] =  0x15; /*The format for the intermediate file
                                    does not allow the user to control
                                    the bits in the first octet of the
                                    second header.  */
         header_block[1] = ((data->eh_unused  & 0x3) << 6)
                         |  (data->eh_2nd_sap & 0x3f);
         header_block[2] =   data->mfid[0]     & 0xff;
         header_block[3] =   data->source[0]  & 0xFF;
         header_block[4] = ( data->source[1]  & 0xFF00)>>8;
         header_block[5] =   data->source[1]  & 0xFF;
         header_block[6] = ( data->eh_reserved[0]  & 0xFF00)>>8;
         header_block[7] =   data->eh_reserved[0]  & 0xFF;
         header_block[8] = ( data->eh_reserved[1]  & 0xFF00)>>8;
         header_block[9] =   data->eh_reserved[1]  & 0xFF;
         header_crc = crc_ccitt ( header_block );
         header_block[10] = 0xff & (header_crc >> 8);
         header_block[11] = 0xff &  header_crc;
         for ( j=0;  j<12;  i++,j++ )
```



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```
                  data_octets[i] =  header_block[j];
        }
        for ( j=0;  j<data->nbytes;  i++,j++ )
        {
            data_octets[i]   = data->data[j] & 0xff;
/*            printf("data_octet[%d] = %02x\n",i,data_octets[i]);*/
        }
        if(data->sap == 0x1f)
             data->nbytes+=12;
        if(i%12 > 8) /* i = number of data octets that will be packed
                           and framed up */
            blocks_to_follow = i/12+2;
        else                                /* data_in_last_block <=12 */
            blocks_to_follow = i/12+1;
        for ( i=0; i<150; i++ )for(j=0;j<6;j++)data_output[i][j] = 0;
/*        for(i=0; i < 12 ;i++)
           printf("h_b[%d] = %02x\n",i,header_block[i]);*/
        /* Get data ready to turn into blocks. */
        if ( data->nbytes > 0 )
        {
           data_crc = crc_32 ( data->nbytes, data_octets );
           for ( i=data->nbytes+3; i>=data->nbytes; i--)
           {
                data_octets[i] = 0xff & data_crc;
                /*printf("data_crc[%d] = %02x\n",i,data_octets[i]);*/
                data_crc = data_crc >> 8;
           }
        }
        data_block_number = 0;

        /* There are 24 frame sync dibits
                     32 NID dibits
                     98 dibits for each block (add 1 for header block)
        */
        /* Total di_bits = fs + nid + header + btf(non term) + term
                    (btf should include the enhanced block, if it exists. */
        data_block_di_bit = 98;             /* number of dibits in array */
        total_di_bits = 24 + 32 + 98 * (1 + blocks_to_follow);
        total_microslots = (total_di_bits + 34)/35;
        total_di_bits += total_di_bits/35;/*Allow for embedded busy bits*/
        microslot = 0;  word = 0;
        for ( i=0;  i<36*total_microslots;  i++ )
        {
            data_output[microslot][word]=data_output[microslot][word]<<2;
            if ( i%36 == 35 )               /* Status Symbol    */
            {
                if((ss_count%data->microslots_per_slot == 0)
                   && (data->outbound == 1))
                    status_for_this_slot = IDLE_SS;
                else
                    status_for_this_slot = data->status;
                ss_count++;
                data_output[microslot][word] |= status_for_this_slot;
            }
            else if ( i < 24 )              /* Frame Sync       */
            {
                data_output[microslot][word] |= extract_dibit(3,16,fs);
            }
            else if ( i < 57 )              /* Network ID       */
```



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```
        {
            data_output[microslot][word] |= extract_dibit(4,16,nid);
        }
        else if ( i < total_di_bits )   /* Data Block Unpacking    */
        {
            data_output[microslot][word] |= extract_dibit(14,14,data_block);
            data_block_di_bit--;
        }
        else                            /* Trailing nulls   */
        {
            data_output[microslot][word] |= 0;
        } /* Data blocks (non-header) */
        if ( data_block_di_bit <= 0 && data_block_number<blocks_to_follow)
        {
            trellis_1_2_encode ( &data_octets[12*data_block_number],
                                 data_block );
            data_block_di_bit = 98;
            data_block_number++;
        }
        if ( i%6 == 5 )  word++;
        if ( word == 6 )  {  microslot++;  word = 0; }
    }
    for ( i=0; i<total_microslots; i++ )
    {
         for ( j=0; j<6; j++ )
            fprintf(out, "%03x", data_output[i][j]);
         if ( i % 2 == 1)
            fprintf(out, "\n");
    }
    if ( (i-1) % 2 == 0)
       fprintf(out, "\n");

   return(0);
}
```



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```
/*************************************************************************

               Name:  find_system_config()
             Author:  Bob LoGalbo
               Date:  5/1/96

   This routine will find the initial parameters
   OUTBOUND and MICROSLOTS PER SLOT.


*************************************************************************/
int find_system_config(infp,pp)
FILE *infp;
struct parm *pp;

   {
   int dest_buff[4];        /* temporary buffer */
   char inbuff[256];        /* character input buffer */

   while (fgets(inbuff,256,infp) != NULL)
      {
      if (find_value("OUTBOUND",inbuff,1,&pp->outbound) != NULL);
      else if (find_value("MICROSLOTS PER SLOT",inbuff,1,&pp->microslots_per_slot)
            != NULL)
               return(0);
      }
   return(-300);
}
```



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```
/*************************************************************************

                Name:  find_fs()
              Author:  Bob LoGalbo
                Date:  5/1/96

   This routine will find the Frame Sync.

*************************************************************************/
int find_fs(infp,pp)
FILE *infp;
struct parm *pp;

   {
   int dest_buff[4];       /* temporary buffer */
   char inbuff[256];       /* character input buffer */

   while (fgets(inbuff,256,infp) != NULL)
      {
      if (find_value("FS",inbuff,3,pp->fs) != NULL) return(0);
      }
   return(-200);
}
```



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```
/*****************************************************************************

                Name:  read_tsbk()

This function will read in the values necessary to create TSBKs. This function
accepts as input hexadecimal values.   The packet values must be presented with
the following labels and in the following order:

SS      : 1
TSBK #1:
OCTET 0 : 15         LB = 0; P = 0; Opcode = 35
MFID    : df
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 01
OCTET 6 : 82
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 00
TSBK #2:
OCTET 0 : 15         LB = 0; P = 0; Opcode = 15
MFID    : c0
OCTET 2 : 00
OCTET 3 : 00
OCTET 4 : 00
OCTET 5 : 02
OCTET 6 : 00
OCTET 7 : 00
OCTET 8 : 00
OCTET 9 : 00
TSBK #3:
OCTET 0 : 15         LB = 1; P = 0; Opcode = 01
MFID    : 23
OCTET 2 : 45
OCTET 3 : 67
OCTET 4 : 89
OCTET 5 : ab
OCTET 6 : cd
OCTET 7 : ef
OCTET 8 : 00
OCTET 9 : 00

          All values should be right justified.  (e.g. all SS fields should
          have a value between 0 to 3 inclusive, because any higher value will
          have the MSB's truncated, etc.)

*****************************************************************************/
int read_tsbk(infp,pp)
   FILE *infp;            /* Input file pointer */
   struct parm *pp;    /* parameter packet */
{
 int tmp;
 char inbuff[256];      /* line input buffer */
 char *sp;              /* pointer to next char in line input string */
 int data_cnt;
 int block_count=0;
 char *store_sp;  /* save the string pntr in case of error on missing field */
```



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```
 if (find_file_value(infp,"SS",inbuff,1,&pp->status) == NULL) return(-100);
 do{
   if (fgets(inbuff,256,infp) == NULL) return(-101);      /* Header line */
   if ((sp = find_file_value(infp,"OCTET 0",inbuff,1,&pp->ignored)) == NULL)
       return(-102);
   /* Read unused bits */
   if ((sp = find_value("LB",sp,1,&pp->lb[block_count])) == NULL)
       return(-103);
   if ((sp = find_value("P",sp,1,&pp->p[block_count])) == NULL)
       return(-104);
   if (find_value("Opcode",sp,1,&pp->opcode[block_count]) == NULL)
       return(-105);
   if (find_file_value(infp,"MFID",inbuff,1,&pp->mfid[block_count]) == NULL)
       return(-106);
   if ((find_file_value(infp,"OCTET 2",inbuff,1,&pp->octet2[block_count]))==NULL)
       return(-107);
   if ((find_file_value(infp,"OCTET 3",inbuff,1,&pp->octet3[block_count]))==NULL)
       return(-108);
   if ((find_file_value(infp,"OCTET 4",inbuff,1,&pp->octet4[block_count]))==NULL)
       return(-109);
   if ((find_file_value(infp,"OCTET 5",inbuff,1,&pp->octet5[block_count]))==NULL)
       return(-110);
   if ((find_file_value(infp,"OCTET 6",inbuff,1,&pp->octet6[block_count]))==NULL)
       return(-111);
   if ((find_file_value(infp,"OCTET 7",inbuff,1,&pp->octet7[block_count]))==NULL)
       return(-112);
   if ((find_file_value(infp,"OCTET 8",inbuff,1,&pp->octet8[block_count]))==NULL)
       return(-113);
   if ((find_file_value(infp,"OCTET 9",inbuff,1,&pp->octet9[block_count]))==NULL)
       return(-114);
    } while(!pp->lb[block_count++]);
    pp->block_count = block_count ;
}
```



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```
/*****************************************************************************

            Name:  data()

This function will read in the values to determine the data format as well as
other header field values.  A case statement driven off of the Format field will
call the format specific routines to finish reading in the data packet, process
them, and print them out.

Note the value following OCTET 0 is ignored, and only the Unused, ANb, IbO and
Format are read in.  This function accepts as input hexadecimal values, in the
following order:

SS    : x
xxxonfirmed Header Block
    OCTET 0 : xx        Unused = x; ANb = x; IbO = x; Format = xx


       x is a hex number and should have values right justified.
       (e.g. all SS fields should have a value between 0 to 3 inclusive, because
       any higher value will have the MSB's truncated, etc.)

NOTE:  The following field values must precede the SS line above:
Packet Data Unit - 0
FS    : 5575 F5FF 77FF
NID   : 293C          NAC = 293; DUID = C
These 2 lines were read in by the Main() function below.
*****************************************************************************/


int data(infp,outfp,pp)
   FILE *infp;         /* Input file pointer */
    FILE *outfp;
   struct parm *pp;    /* parameter packet */

   {
    int tmp;
   char inbuff[256];   /* line input buffer */
   char *sp;    /* pointer to next char in line input string */
    int data_cnt;
   char *store_sp;/* save the string pntr in case of error on missing field */

   if (find_file_value(infp,"SS",inbuff,1,&pp->status) == NULL) return(-100);
   if (fgets(inbuff,256,infp) == NULL) return(-101);    /* Header line */
   if ((sp = find_file_value(infp,"OCTET 0",inbuff,1,&pp->ignored)) == NULL)
       return(-102);
   /* Read unused bits */
   if ((sp = find_value("Unused",sp,1,&pp->unused0)) == NULL) return(-103);
   /* Read confirmation flag if conf or unconf data */
   store_sp = sp;
   if ((sp = find_value("ANb",sp,1,&pp->anb)) == NULL)
       {
       sp = store_sp;
       store_sp = NULL;
       }

   if ((sp = find_value("IbO",sp,1,&pp->ibo)) == NULL) return(-104);
   if (find_value("Format",sp,1,&pp->format) == NULL) return(-105);
```



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```
switch(pp->format)
   {
   case 0x17:                        /* Confirmed Data */
        tmp=read_alternate_control(infp,pp);
      if( tmp < 0)
         printf("e =%d Invalid Alternate Conrol Data File. \n\n",tmp);
      else
        {
         process_and_print_alternate_control(outfp,pp);
        }
      break;
   case 0x15:                        /* Unconfirmed Data */
        tmp=read_unconf_data(infp,pp);
      if( tmp < 0)
         printf("e = %dInvalid Unconfirmed Data File. \n\n",tmp);
      else
         process_and_print_unconfirmed(outfp,pp);
      break;
   default:
      printf("\nInvalid Data Format Specified. \n\n");
      break;
   }

return(0);
}
```



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```
/************************************************************************

                Name:  read_alternate_control()

This function will read in the values necessary to create alternate control
data packets. This function accepts as input hexadecimal values. The packet
values must be presented with the following labels and in the following order:

SS      : 1
Multiple Trunked Block OSP:
OCTET 0 : 37         Unused = 0; ANb = 0; IbO = 1; Format = 17
OCTET 1 : c0         Unused = 3; SAP = 00
MFID    : 00
LLID    : 00 0001
OCTET 6 : 83         FMF = 1; Blocks to Follow = 02
OCTET 7 : 0b         Unused = 0; Opcode = 08
OCTET 8 : 00         Trunked Message 1 = 00
OCTET 9 : 00         Trunked Message 2 = 02
Data Block:
00 01 02 03 04 05 06 07 08 09 0a 0b 00 00 00 00 00 00 00 00
#
          All values should be right justified.
          (e.g. all SS fields should have a value between 0 to 3
          inclusive, because any higher value will have the MSB's truncated,
          etc.)


************************************************************************/
int read_alternate_control(infp,pp)
   FILE *infp;            /* Input file pointer */
   struct parm *pp;    /* parameter packet */

   {
   char inbuff[256];      /* line input buffer */
   char *sp;           /* pointer to next char in line input string */

   if ((sp = find_file_value(infp,"OCTET 1",inbuff,1,&pp->ignored)) == NULL)
       return(-1);
   if ((sp = find_value("Unused",sp,1,&pp->unused1)) == NULL)
       return(-2);
   if (find_value("SAP",sp,1,&pp->sap) == NULL) return(-3);
   if (find_file_value(infp,"MFID",inbuff,1,&pp->mfid[0]) == NULL) return(-4);
   if (find_file_value(infp,"LLID",inbuff,2,pp->dest) == NULL) return(-5);
   if ((sp = find_file_value(infp,"OCTET 6",inbuff,1,&pp->ignored)) == NULL)
       return(-6);
   if ((sp = find_value("FMF",sp,1,&pp->fmf)) == NULL) return(-7);
   if (find_value("Blocks to Follow",sp,1,&pp->btf) == NULL) return(-8);
   if ((sp = find_file_value(infp,"OCTET 7",inbuff,1,&pp->ignored)) == NULL)
       return(-9);
   if ((sp = find_value("Unused",sp,1,&pp->unused7)) == NULL) return(-10);
   if (find_value("Opcode",sp,1,&pp->opcode[0]) == NULL) return(-11);
   if ((sp = find_file_value(infp,"OCTET 8",inbuff,1,&pp->ignored)) == NULL)
       return(-12.1);
   if ((find_value("Trunked Message 1",sp,1,&pp->tm1)) == NULL) return(-12.2);
   if ((sp = find_file_value(infp,"OCTET 9",inbuff,1,&pp->ignored)) == NULL)
       return(-13);
   if ((find_value("Trunked Message 2",sp,1,&pp->tm2)) == NULL) return(-14);
   if (fgets(inbuff,256,infp) == NULL) return(-1);          /* Header line */
```



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```
    /* Read in the data block */
    if (read_data_block(infp,pp) == -1) return(-31);

    return(0);
}
```



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```
/*****************************************************************************

                Name:  read_unconf_data()

This function will read in the values necessary to create unconfirmed data
packets. This function accepts as input hexadecimal values.   The packet values
must be presented with the following labels and in the following order:

    OCTET 1 : DF        Unused = 3; SAP = 1F
    MFID    : 00
    LLID    : 00 0001
    OCTET 6 : 84        FMF = 1; Blocks to Follow = 04
    OCTET 7 : 06        Unused = 0; Pad = 06
    Reserved: 00
    OCTET 9 : 02        Unused = 0; Offset = 02
Data Block:
    55 F9 91 A9 78 EB 9A 54 00 81 00 01 E0
    B7 AD 98 26 3A 43 EF AC 2E 39 0C 8C 32 74 FD 6E 88 E1 6D
#
          All values should be right justified.  (e.g. all SS fields should
          have a value between 0 to 3 inclusive, because any higher value will
          have the MSB's truncated, etc.)


*****************************************************************************/
int read_unconf_data(infp,pp)
   FILE *infp;             /* Input file pointer */
   struct parm *pp;    /* parameter packet */

   {
   char inbuff[256];       /* line input buffer */
   char *sp;           /* pointer to next char in line input string */

   if ((sp = find_file_value(infp,"OCTET 1",inbuff,1,&pp->ignored)) == NULL)
        return(-1);
   if ((sp = find_value("Unused",sp,1,&pp->unused1)) == NULL) return(-2);
   if (find_value("SAP",sp,1,&pp->sap) == NULL) return(-3);
   if (find_file_value(infp,"MFID",inbuff,1,&pp->mfid[0]) == NULL) return(-4);
   if (find_file_value(infp,"LLID",inbuff,2,pp->dest) == NULL) return(-5);
   if ((sp = find_file_value(infp,"OCTET 6",inbuff,1,&pp->ignored)) == NULL)
       return(-6);
   if ((sp = find_value("FMF",sp,1,&pp->fmf)) == NULL) return(-7);
   if (find_value("Blocks to Follow",sp,1,&pp->btf) == NULL) return(-8);
   if ((sp = find_file_value(infp,"OCTET 7",inbuff,1,&pp->ignored)) == NULL)
       return(-9);
   if ((sp = find_value("Unused",sp,1,&pp->unused7)) == NULL) return(-10);
   if (find_value("Pad",sp,1,&pp->pad) == NULL) return(-11);
   if (find_file_value(infp,"Reserved",inbuff,1,pp->reserved) == NULL)
       return(-12);
   if ((sp = find_file_value(infp,"OCTET 9",inbuff,1,&pp->ignored)) == NULL)
       return(-13);
   if ((sp = find_value("Unused",sp,1,&pp->unused9)) == NULL) return(-14);
   if (find_value("Offset",sp,1,&pp->offset) == NULL) return(-15);

   /* Read Enhanced Addressing header if SAP = 0x1F */
   if (pp->sap == 0x1F)
      {
      if (fgets(inbuff,256,infp) == NULL) return(-17);  /* Header line */
      if ((sp = find_file_value(infp,"2ND SAP",inbuff,1,&pp->ignored))==NULL)
```



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```
            return(-18);
        if ((sp = find_value("Unused",sp,1,&pp->eh_unused)) == NULL)
            return(-19);
        if (find_value("SAP",sp,1,&pp->eh_2nd_sap) == NULL) return(-20);
        if (find_file_value(infp,"SOURCE",inbuff,2,pp->source) == NULL)
            return(-21);
        if (find_file_value(infp,"RESERVED",inbuff,2,pp->eh_reserved) == NULL)
             return(-22);
        }

    if (fgets(inbuff,256,infp) == NULL) return(-1);          /* Header line */


    /* Read in the data block */
    if (read_data_block(infp,pp) == -1) return(-31);

    return(0);
}
```



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```
/*****************************************************************************

                Name:  main()
                Date:  3/6/96

  The switch statement will switch off of the DUID just read in, then pick the
  case statement to read in, error encode, order and print the frames/packets.
  It will then go onto the next info block and read in the subsequent DUID.

  The routine will continue to read in data until the input file is exhausted.

  The main routine reads in the following fields that drive the switch
  statement below:

FS      : 5575 F5FF 77FF
NID     : xxxx          NAC = xxx; DUID = x
*****************************************************************************/



#include <stdio.h>
#include <string.h>
#include "parm.h"  /* This include file contains the structure whose
                      elements compose the various components of CAI frames.*/

void main(argc,argv)
   int argc;
   char *argv[];

   {
   FILE *infp;             /* Input file pointer */
   FILE *outfp;        /* Output file pointer */
   struct parm p,*pp;      /* parameter packet */

   char inbuff[256];       /* line input buffer */
   char *sp;           /* pointer to next char in line input string */
   int i;              /* loop counter */
    int debug_var;

   /* Initialize parameters */
   pp = &p;

   /* GET INPUT FILE */
    strcpy(inbuff,argv[1]);
    if (inbuff[0] == '\0')
      {
     printf("Default input <clear.dat> assumed; no input file specified.\n");
      strcpy(inbuff,"clear.dat");
      }
   while((infp = fopen(inbuff,"r")) == NULL)
       {
       printf("Input file %s does not exist.\n",inbuff);
       printf("\nEnter input file name: ");
       gets(inbuff);
       }
    /* GET OUTPUT FILE */
    strcpy(inbuff,argv[2]);
   if (inbuff[0] == '\0') outfp = stdout;
   else if ((outfp = fopen(inbuff,"w")) == NULL)
```



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```
      {
      printf("Output file %s cannot be opened.\nSTDOUT by default.\n\n",inbuff);
      outfp = stdout;
      }

     /* Determine the system configuration */
     if (find_system_config(infp,pp) == -1) exit(-1);

    /* Continue reading input driven by DUID until file is exhausted. */
    while (feof(infp) == 0)
       {
       if (find_fs(infp,pp) == -1) exit(-1);
       if ((sp = find_file_value(infp,"NID",inbuff,1,&pp->ignored)) == NULL)
           exit(-1);
       if ((sp = find_value("NAC",sp,1,&pp->nac)) == NULL) exit(-1);
       if (find_value("DUID",sp,1,&pp->duid) == NULL) exit(-1);
       switch(pp->duid)
          {
          case 0x7:
                debug_var = read_tsbk(infp,pp);
             if( debug_var <= -1)
                printf("e= %d ***Invalid TSBK File.******\n\n",debug_var);
             else
                {
                    build_tsbk_and_print(pp,outfp);
                }
             break;
          case 0xC:
                 debug_var = data(infp,outfp,pp);
               if( debug_var <= -1)
                printf("e= %d Invalid Data Header File.*\n\n",debug_var);
             break;
          default:
             printf("*Undefined DUID (%X) specified!**\n\n",pp->duid);
             break;
          }
       }
    fclose(infp);
    fclose(outfp);
    }


char *find_file_value(infp,pattern,source,number,dest)
    FILE *infp;             /* Input file pointer */
    char *pattern;          /* Character string to be found */
    char *source;        /* pointer to the input string */
    int number;             /* number of integer values to be returned */
    int *dest;              /* destination array of integers */

    {
    if (fgets(source,256,infp) == NULL) return(NULL);
    return (find_value(pattern,source,number,dest));
    }

char *find_value(pattern,source,number,dest)
    char *pattern;          /* Character string to be found */
    char *source;        /* pointer to the input string */
    int number;             /* number of integer values to be returned */
    int *dest;              /* destination array of integers */
```



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```
   {
   int i;              /* loop counter */
   char *eol;              /* end of line pointer */

   i = 0;
   eol = strchr(source,'\0');
   while(isspace(*source)) source++;
   if (*pattern != (char)NULL)
      if (strncmp(pattern,source,(int)strlen(pattern)) != 0) return(NULL);
   source = strtok(source,":=");
   for (i = 0; i < number; ++i)
      {
      source = strtok(NULL," \n\0");
      sscanf(source,"%x",&*dest++);
      }
   source = strchr(source,'\0');
   if((unsigned char*)source < (unsigned char*)eol) source++;
   return(source);
   }

/*********************** DATA UTILITIES ***********************/

/* READ DATA BLOCK */
int read_data_block(infp,pp)
   FILE *infp;             /* Input file pointer */
   struct parm *pp;    /* parameter packet */

   {
   char inbuff[256];       /* line input buffer */
   char *sp;           /* pointer to next char in line input string */
   int temp;           /* number conversion buffer for sscanf */

    /* Input the data */
    pp->nbytes = 0;
    while(fgets(inbuff,256,infp) != NULL)
      {
      if ((inbuff[0] == '#') || (inbuff[0] == '\0')) break;
      sp = inbuff;
      while(isspace(*sp)) sp++;
      sp = strtok(sp," \t\n\0");
      while(sp != NULL)
         {
         sscanf(sp,"%x",&temp);
         pp->data[pp->nbytes++] = temp & 0xFF;
         if (pp->nbytes >= 545) return(-1);
         sp = strtok(NULL," \t\n");
         }
        }
   return(0);
   }
```



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```
/*****************************************************************************

     Name:  crc.h
   Author:  Al Wilson
     Date:  8/4/93
  History:  8/4/93  New

This module declares three functions:
    crc_ccitt ( pointer )   encodes the header parity check
    crc_9 ( num, pointer )  encodes the confirmed data block parity check
    crc_32 ( length, pointer )      encodes the data parity check
The pointer points to a list of integers.  The 32 bit pointer is a variable
length list.  The first two functions return a 16 bit and a 9 bit result
respectively.  The last function returns a 32 bit long integer result.

*****************************************************************************/

#ifndef CRC_H

#define CRC_H

int crc_ccitt ( int * );
int crc_9     ( int, int * );
long int crc_32 ( int, int * );

#endif
```



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```
/***************************************************************************

     Name:  parm.h
   Author:  Mike Bright
  Version:  1.10
     Date:  3/15/96

***************************************************************************/

#ifndef PARAMETERS_H

#define PARAMETERS_H

struct parm
   {
   /* Encryption parameters */
   int ep_algid;       /* 1 octet ALGORITHM ID for the KEK*/
   int ep_keyid;       /* 2 octet KEY ID for the TEK */
   int iv[4];          /* 8 octet Initialization Vector */
   long tek[2];        /* 8 octet TEK */
   int flags;          /* Valid parm; bit- 0:key 1:iv 2:keyid 3:algid; 1->valid */

   /* Channel Access parameters */
   int fs[3];          /* 6 octet Frame Sync bit pattern */
   int nac;            /* 12 bit NAC */
   int duid;           /* 4 bit DUID */

   /* Voice/Data Parameters */
   int mfid[3];        /* 1 octet Manufacturer ID */
   int mi[5];          /* 9 octet MI (left justified - last octet not used) */
   int ss[256];        /* Status Symbols buffer */

   /* Data specific parameters */
   int unused0;        /* 1 or 2 bits unused in octet 0 of the data header */
   int anb;            /* 1 bit confirmation required (1 = confirmation) */
   int ibo;            /* 1 bit direction (1 = outbound; 0 = inbound) */
   int format;         /* 5 bits defining data packet format */
   int unused1;        /* 2 bits unused in octet 1 of the data header */
   int sap;            /* 6 bit SAP value */
   int dest[2];        /* 3 octet destination LLID (right justified) */
   int fmf;            /* 1 bit Full Message Flag */
   int btf;            /* 7 bits number of blocks to follow */
   int unused7;        /* 3 bits unused in octet 1 of the data header */
   int pad;            /* 5 bits number of pad octets */
   int sync;           /* 1 bit sync flag */
   int ns;             /* 3 bit sequence number */
   int fsnf;           /* 4 bit Fragment Sequence Number */
   int unused9;        /* 2 bits unused in octet 1 of the data header */
   int offset;         /* 6 bit header offset */
   int reserved[2];    /* 3 octet reserved buffer for unconfirmed/ACK data */

   /* Enhanced addressing (EA) parameters */
   int source[2];      /* 3 octet source address (right justified) */
   int eh_unused;      /* 2 bits unused in SAP octet */
   int eh_2nd_sap;     /* 6 bits enhanced addressing secondary SAP value */
   int eh_reserved[2]; /* 3 octet reserved for unconfirmed enhanced addressing */

   /* Encryption Sync (ES) header */
   int es_unused;      /* 2 bits unused in ES SAP octet */
```



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```
    int es_2nd_sap;     /* 6 bits encryption sync secondary SAP value */


    /* Data buffer */
    char data[544];     /* Data buffer - includes space for ES, EA & pad + data */

    /* Working storage variables */
    int lfsr[4];        /* LFSR register */
    int ss_pntr;        /* pointer to next status symbol */
    int ss_count;       /* Number of Status Sysbols entered in the data block */
    int nbytes;         /* data octet counter */
    int ignored;        /* buffer to read in integer values to be ignored */

     /* Trunking control channel params */
     int status;
     int outbound;
     int microslots_per_slot;
     int tm1;
     int tm2;
     int lb[3];
     int p[3];
     int opcode[3];
     int octet2[3];
     int octet3[3];
     int octet4[3];
     int octet5[3];
     int octet6[3];
     int octet7[3];
     int octet8[3];
     int octet9[3];
     int block_count;
    };
char *find_file_value(FILE *infp,char *pattern,char *source,int number,int *dest);
char *find_value(char *pattern,char *source,int number,int *dest);
int find_fs(FILE *infp,struct parm *pp);
int read_header(FILE *infp,struct parm *pp);
void print_ep(FILE *outfp,struct parm *pp);
void print_header(FILE *outfp,int seq_num,struct parm *pp);
int read_ldu_1(FILE *infp,struct parm *pp);
void print_ldu_1(FILE *outfp,int seq_no,struct parm *pp);
int read_ldu_2(FILE *infp,struct parm *pp);
void print_ldu_2(FILE *outfp,int seq_no,struct parm *pp);
int read_simp_term(FILE *infp,struct parm *pp);
void print_simp_term(FILE *outfp,int seq_no,struct parm *pp);
int read_term(FILE *infp,struct parm *pp);
void print_term(FILE *outfp,int seq_no,struct parm *pp);
int data(FILE *infp,FILE *outfp,struct parm *pp);
int read_conf_data(FILE *infp,struct parm *pp);
int read_unconf_data(FILE *infp,struct parm *pp);
int read_data_block(FILE *infp,struct parm *pp);
int read_ss_block(FILE *infp,struct parm *pp);
void encrypt_data_block(struct parm *pp);
void print_conf_data(FILE *outfp,int seq_no,struct parm *pp);
void print_unconf_data(FILE *outfp,int seq_no,struct parm *pp);

#endif
```



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```
/*****************************************************************************

     Name:  trellis.h
   Author:  Al Wilson
     Date:  8/5/93
  History:  8/5/93  New

This module declares two functions:
    trellis_3_4_encode ( in, out )    encodes the rate 3/4 trellis code
    trellis_1_2_encode ( in, out )    encodes the rate 1/2 trellis code
The input and output arguments are pointers a integer vectors.  The input
arguments must point to octets while the output arguments point to an array
of 14 integers with 14 bits in each (196 bits in total).

*****************************************************************************/

#ifndef TRELLIS_H

#define TRELLIS_H

void trellis_3_4_encode(int *, int *);
void trellis_1_2_encode(int *, int *);

# endi
```



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```
/*************************************************************************

     Name:  vector_operations.h
   Author:  Al Wilson
     Date:  8/3/93
  History:  8/3/93  New

This module declares two functions for operations on vectors:
    shift_vector_right ( int length, int element_length, int shift, int * ptr )
    extract_dibit ( int length, int element_length, int * ptr )

*************************************************************************/

#ifndef VECTOR_OPERATIONS_H

#define VECTOR_OPERATIONS_H

void shift_vector_right(int, int, int, int * );
int extract_dibit(int, int, int * );

#endif
```



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