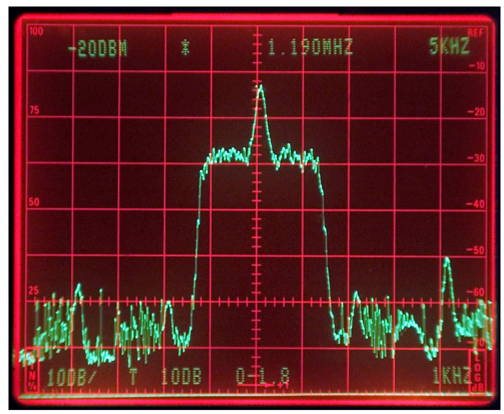
AM Radio Field Strength Measurements with Confidence
November 2004

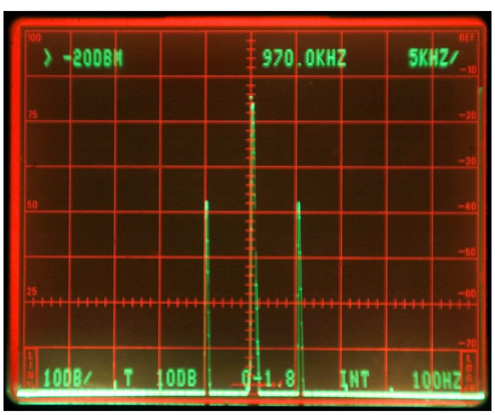
Understanding the AM Broadcast signal

The AM Broadcast service in the United States and many other countries is implemented in 10 kHz channel steps with center frequencies 540 kHz through 1700 kHz, at carrier power levels from 250 watts to 50 kilowatts.

AM field strength or field intensity measurements are made in support of a *reference proof* or *partial proof* for stations with directional antenna arrays, as defined in Section 73.151 and 73.186 of the FCC rules. Knowledge of field strength confirms primary coverage over the city of license, quantifies additional areas served by the station, and assures directional protection of distant co-channel stations. To make consistent and repeatable measurements, it is useful to understand the amplitude modulation process.

Amplitude Modulation products are contained in upper and lower sidebands whose frequency components represent audio frequencies and energy levels represent loudness. Sideband energy is generally contained within +/-10.2 kHz of assigned channel frequency, for an audio bandwidth of approximately 10 kHz. To the right is an example of a talk radio format, with little energy above 7 kHz.





A perfect AM transmitter, modulated with a single sine wave tone would radiate a constant average power regardless of modulation level, with spectral power shared among the assigned frequency carrier and two sideband frequencies above and below the assigned frequency by the frequency of the modulating tone. A field strength meter, or calibrated power bolometer, would read a constant value, with or without a modulating tone. The example at left is from a signal generator modulated with a 5 kHz tone.

Audio Processing

AM radio stations will often use audio processing equipment to maintain a relatively even modulation level. When the audio processor is adjusted to make the audio seem louder, the modulating audio will become non-symmetrical, with negative peaks compressed to avoid driving the transmitter to a zero carrier cutoff and positive modulating peaks stretched to increase the average level of audio available to the receiver. Much development has been done to make audio both loud and good sounding, but the net result is to increase average signal power during audio peaks. When audio proof of performance or field strength measurements are to be made, AM Stations should bypass any processing that makes the audio modulating waveform intentionally non-symmetrical. Bypassing audio processing allows a true picture of Carrier Shift, Audio Distortion, Power Output, and Field Strength.

Organizing AM Field Strength Measurement Tests

Once the fundamentals of an AM broadcast signal are understood, signal coverage testing can be addressed. Assembling a measurement system for AM field strength testing is the next step. Such a system will normally consist of the following items:

- Calibrated AM Receiving Antenna with Antenna Factors
- 30dB Attenuator Pad (optional)
- Low Frequency Block Converter
- Field Strength Meter or a Drive-Test System
- Laptop PC with Windows measurement application (optional)
- GPS Receiver (optional)

By understanding how these tools operate together as a measurement system useful and accurate signal coverage information can be quickly gathered, analyzed and recorded.

Field Strength Measurement Antennas

The measurement receive antenna is physically small compared to the AM Broadcast transmitting antenna. Measurement antennas are individually range calibrated and supplied with an Antenna Factor correction table providing traceability to the National Institute of Standards and Technology.

There are two common measurement antennas for AM Broadcast measurements:

The amplified monopole antenna, such as Z Technology's AA-2R, consists of a ruggedized one-meter vertical rod mounted on a base containing an impedance-matching amplifier, in turn mounted on a small counterpoise. The mounting of this antenna is quite tolerant and it may be attached by its counterpoise to a grounded or ungrounded tripod, directly to the metal top of a vehicle, or handheld. This short vertical antenna is convenient and non-directional for measurements while stopped or driving.

A second popular measurement antenna is the shielded loop. This type of antenna is not as sensitive as the vertical rod antenna, and may be more tolerant of atmospheric noise. It does exhibit a deep null of from 20 – 25 dB that can be oriented to minimize interference from a point-source noise or a distant co-

channel station. The null is bi-directional, however, sometimes limiting the measurement effectiveness when the station's antenna pattern null is in a reciprocal direction to the station being protected.

Both the measurement monopole and shielded loop antennas cover the full AM Broadcast band and are relatively stable over a variety of environmental conditions.

Antenna factors

Calibrated measurement antennas are provided with calibration tables to normalize NIST traceable RF field strength measurements throughout the industry. By using NIST traceable antennas, field strength meters, and other traceable components, manufacturers, users, and the FCC can communicate signal values without the necessity of shipping measurement equipment or designing it to some theoretical specification. Calibrated measurement antennas are individually range-measured and supplied with correction values for frequencies of interest. When these correction factors are added to similar factors for connecting cables, filters, etc., the total 'antenna factor' may be used as a field strength correction factor to convert measured values directly into field strength in dBuV/m indicating the real, available RF field.

Field Strength Meters

Modern field strength meters such as the Z Technology R-506 and R-507 are calibrated and traceable to NIST over the specified operating range. Because these instruments contain microprocessors and memory to store and recall calibration data, field calibration is not required. Both the R-506 and R-507 (which includes a spectrum display capability for television measurements) may be used with a BC-BCB calibrated block converter (shown here attached to the front of the field strength meter) for AM Broadcast measurements. Power is accepted at the instrument's 50-ohm input and power levels are reported in the desired dBm, dBuV, or with the antenna factor, field strength directly in dBuV/m. Older designs report in uV, which is the antilog of dBuV divided by 20. A units conversion table is provided as Appendix C.

Z Technology field strength meters are fully programmable and may be operated in a system under a Windows application to measure, view, and document field strength related values. Software applications supplied with the field strength meter can automate the measurement of multiple stations, record GPS locations, graphically display measurements, and record data for export to other applications. Modern field strength measurement instruments can accumulate accurate data much faster and more flexibly than early models.

Equipment calibration

The Z Technology Field Strength Meter is a 50 ohm input measurement instrument calibrated and traceable to the National Institute of Standards and Technology over the full range of frequencies, power levels, and operating temperatures specified in its instruction manual. When measuring AM Broadcast signals, the field strength meter is set to an IF bandwidth of 15 kHz (Narrow setting) and accepts the signal from a calibrated unity gain BC-BCB block converter. This configuration covers a frequency range of 0.3 –3.0 MHz, with a power input level range of -97dBm to –17dBm (+10 dBuV to +90 dBuV).

In the development of recommendations, Z Technology has characterized measurement system performance with AM Broadcast signals at several different input power levels +30 to + 60dBuV; several input frequencies from 500 kHz to 2.0 MHz, and at various modulation frequencies from 400Hz to 10 KHz. The AM signal source was an HP-8640B signal generator calibrated with an HP-435A/8482A Power Meter and bolometer traceable to NIST. Test results indicate that for AM modulation levels from zero to 60%, the power level reported by the field strength meter was found to vary a maximum of 1.1 dB. A reading of -1.1 dB occurred with a 1KHz audio modulation of 60%. At all other frequencies tested the worst power level reading was -0.8dB. At a 90% modulation level, input power level was found to change by -3.2dB at 1 kHz. At all other frequencies tested the worst power level change was -2.3dB.

Field testing with AM radio stations with several different program formats confirms readings can be reliable and as expected for a modulated AM signal and are considered within a reasonable range of calibrated measurement. To remove any uncertainty, it is still recommended measurements not be taken during periods of excessive modulation.

AM Broadcast field strength measurement suggestions:

Operator safety and comfort are always worthy of consideration. Personnel should always take care when working near power lines, in the presence of electrical storms or in high RF fields.

Turn off any non-symmetrical audio processing. Audio leveling is OK, but heavily compressed audio will increase average RF power and make the field strength reading more program content dependant. Use the field strength meter's AM demodulator and speaker to confirm any undesired program content.

For spot location measurements, such as confirmation of monitoring points and maintenance of the nulls in a directional transmitting array, the suggested antenna would be the shielded loop antenna. The loop antenna is preferred because it seems to be more resistant to noise and may be able to measure a deeper pattern null. It can also be manually rotated to null any interfering co-channel signals that are off-axis to the direction of the station's antenna pattern null.

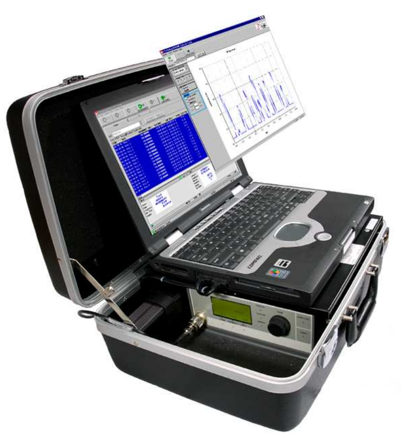
For signal coverage measurements, the recommended antenna system is the AA-2R Ruggedized Active Monopole Antenna with AA-2M Magnetic Mount. This antenna may be attached to a metal vehicle rooftop and connected to the field strength meter with a flexible 50 ohm connecting cable. Drive testing confirms that, with a rooftop-mounted antenna, vehicle direction and adjacent automobile traffic has little effect on signal strength. As expected, the major effect, dips as much as 10 – 15 dB, occurs when driving directly under power lines.

Both the shielded loop and monopole antennas are quite tolerant of mounting location. Antenna height has little effect on signal strength at AM broadcast frequencies, but it makes sense to measure under typical listener locations. Select a location that is generally clear of large obstructions and power lines. Antennas need not be grounded, and may be hand held, tripod mounted, or attached to a vehicle rooftop. A loop antenna must be physically oriented to account for its deep broadside null. The short vertical monopole is essentially non-directional.

As with the antenna, there are selections to be made for the measurement instrument.

Manual monitoring point measurements are easily made with the basic field strength meter. Modern field strength meters are battery operated, quite small, require no field calibration, may be programmed to account the antenna factor, and may be set to read directly in the desired measurement units.

For automatic measurement of signal coverage, programmable field strength meters may be attached to a laptop PC with Z Technology application software recording field strength information along with GPS locations for subsequent display using Microsoft MapPoint. Recorded field strength data is in clear text for easy recovery and analysis using commodity office productivity applications such as Microsoft Excel or MapPoint.



An automatic measurement system can be as simple as an R-506 Programmable Field Strength Meter with a BC-BCB block converter and antenna, attached to the users laptop PC running Z Technology Windows software. Measurement systems with additional capabilities, for multiple-station measurements, coverage mapping, portable packaging, AC/DC power operation are available factory configured. DriveTest application software automates measurement and documentation, and the operator can enter comments or flag unusual conditions with a simple mouse-click. Recovery of specific information for any location in the drive is also quite straightforward, as are running averages for strings of individual locations. Any of the system configurations on the Z Technology website, www.ztechnology.com, may be used with a Z Technology BC-BCB block converter and appropriate antenna for AM Broadcast measurements.

A sample step-by-step measurement checklist is attached as Appendix A, along with several useful charts as subsequent appendices.

Conclusions and Recommendations:

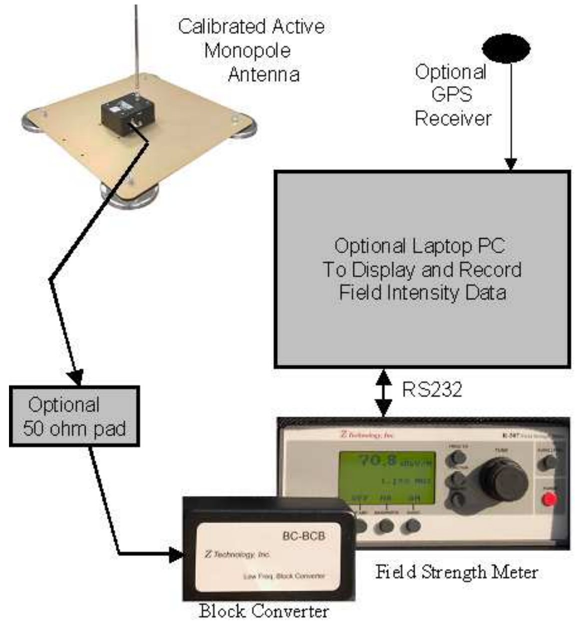
Both AM Broadcast monitoring point and signal coverage measurements are fast and accurate with modern, programmable equipment. Procedures are easily understood and completely repeatable. By selection of an appropriate antenna, the same field strength measurement instrument or system can be optimized for both monitoring point and signal coverage applications.

Signal coverage measurements over a wide area are now practical with systems utilizing Z Technology's operating software. Modern measurement systems and fully developed software applications gather and map massive amounts of RF signal strength data to provide the accurate coverage information needed by the AM Broadcaster's technical and business operations.

The gathering of this critical signal coverage information is now practical and economical with modern, programmable measurement instrumentation.

APPENDIX A
Procedure for Mobile Field Strength Measurements

1. Assemble your measurement system:
    a. Programmable field strength meter with fresh battery
        i. Block converter for AM Broadcast band
        ii. 30 dB 50 ohm pad for strong signals
        iii. Laptop PC/software/GPS receiver or pad/pen to record readings
    b. Calibrated Measurement Antenna and cable:
        i. Active monopole antenna for mobile coverage measurements
        ii. Antenna Factor table



2. Mount measurement system in/on vehicle:
    a. Confirm that the measurement antenna can be mounted safely; clear of mechanical interference and well clear of power lines.
    b. Attach antenna on magnetic mount to roof of vehicle
        i. Antenna location is not critical, but care should be taken to use a good mechanical attachment, with antenna element clear of other obstructions.
    c. Route cable to block converter/meter input
        i. Avoid pinch damage to the calibrated cable.
        ii. Keep cable clear of vehicle operating controls.
    d. Connect meter to DC power or operate from internal battery
        i. Attach block converter and connect block converter power cable to accessory DC output of meter.
        ii. To minimize electrical noise interference from the vehicle, connect the grounding terminal on the block converter to a good vehicle ground.
    e. If operating from an external switching power supply or AC/DC inverter, confirm that power supply radiation does not interfere with measurement accuracy. This is easily checked by switching to battery power and turning off any external supply.

3. Enter the following information into Field Strength Meter or PC application if the meter is connected to your laptop:
    a. If making manual measurements from the FSM front panel:

    i. Select direct low frequency readout using meter Function 13. This is done by selecting F13 on the meters front panel and setting the instrument to then BC.
    ii. Set BANDWIDTH to 15 kHz (NB)
    iii. Turn FSM RF Amplifier OFF
    iv. Set AUDIO to AM (This setting does not affect measurements in any way. It only affects the detector driving the internal speaker.)
    v. If not in the dBuV read out mode, set measurement units to dBuV using meter function F14 (switches between dBm and dBuV) and confirm signal strength is within range (+90dBuV to +10dBuV) (-17dBm to –97dBm) of field strength meter. If the signal to be measured is larger than –17dBm +90dBuV the SIGNAL LEVEL readout will display "> -17 dBm 90dBuV " with the ">" sign blinking. A calibrated 30 dB, 50 ohm coaxial pad may be installed at input to block converter if signal strength is too high.
    vi. Set measurement units to dBuV/m using meter function F15 (F15 activates inclusion of Antenna Factors from the resident table within the meter. This resident table is unique to your calibrated antenna and may be programmed into your meter using the supplied Load_Tab.exe application.)
    vii. Read field strength directly in dBuV/m on Field Strength Meter front panel.
  b. If making measurement using the PC application:
    i. Set BANDWIDTH to 15 kHz (NB)
    ii. Turn FSM RF Amplifier OFF
    iii. Set AUDIO to AM (This setting does not affect measurements in any way. It only affects the detector driving the internal speaker.)
    iv. Using the FSM front panel, confirm that the meter reads in the dBuV. If not in the dBuV read out mode, set measurement units to dBuV using meter function F14 (switches between dBm and dBuV) and confirm signal strength is within range (+90dBuV to +10dBuV) of field strength meter. If the signal to be measured is larger than +90dBuV the SIGNAL LEVEL readout will display "> 90dBuV " with the ">" sign blinking. A calibrated 30 dB, 50 ohm coaxial pad may be installed at input to block converter if signal strength is too high.
    v. Place the FSM in Remote mode by selecting function 93 (F93) on the meter front panel.
    vi. Connect the meter to the PC serial port
    vii. Launch the Application by double clicking on the desktop icon.
    viii. Enter antenna factor for sum of antenna and cable and pad (if used)
    ix. Read field strength directly in dBuV/m on the PC display.

4. For mobile measurements using Z Technology GPS aware software:
  a. As described in an earlier section, set frequency, bandwidth, block converter offset, antenna factor, and readout mode on the FSM front panel.

b. Select readout units in dBuV to be sure signal at the FSM input is within the range +90dBuV to +10dBuV. Install 50 ohm pad at input to block converter if signal strength is too high.
c. Place the FSM in Remote mode by selecting function 93 (F93) on the meter front panel.
d. Connect the meter to the PC serial port.
e. Launch the Application by double clicking on the Desktop icon.
f. Select the GPS-enabled option within the application.
g. Attach USB GPS receiver to one of the available USB ports on the PC.
    i. Launch the application and check to see that the PC is communicating with the GPS receiver. (See the Z Technology application note concerning communicating with a GPS receiver.)
        1. After a long storage period, or when using the GPS receiver for the first time at a new location, the receiver may take up to ten minutes to acquire a full catalog of satellite information. Subsequent startup times will usually be less than one minute from turn on.
h. Observe signal strength and location readouts on screen
i. Start recording and drive in coverage area
j. Export data file to Microsoft MapPoint for a plot of signal strength, or to Microsoft Excel for additional analysis.
k. The system will display and/or record actual field strength values at each measurement location. It is useful to make note of surrounding conditions, such as overhead power lines, tunnels, bridge structures, etc., that would be expected to affect the reading.

APPENDIX B
Working with Antenna Factors

Antenna Factors are the key to accommodating all of the external variables affecting the field strength meter reading to finally display the signal field strength available to the measurement system. The field strength meter reads power delivered at its input connector in dBm, where 0 dBm equals 1 milliwatt into a 50 ohm load.

A table is easily generated to convert between dBm, a direct reading of power, and voltage (including millivolts and microvolts) when the load impedance is known (50 ohms for RF measurement instruments). Such a table is included as APPENDIX C. Working in logarithmic dBuV units, then, lets us easily account for antenna gain or losses, cable loss, and any other losses in our measurement system. By simply adding all of the losses to the dBuV reading, we can know the real field strength available to any antenna we may place in that field. This field strength is usually expressed in dBuV/meter.

A programmable field strength meter or a PC application can do these calculations and measurement unit conversions for you, but you must provide the instrument or PC an 'antenna factor'.

The antenna factor is derived from the sum of values measured with a calibration system traceable to the National Institute of Standards and Technology. For measurement antennas, the antenna factor is recorded on a calibrated antenna range by comparison to a reference antenna on the same frequency. For measurement antennas in the AM Broadcast band, the antenna remains physically the same over the band, and a table of antenna factors will be developed by comparison to the reference antenna over the band.

It is important to sum all of the applicable correction factors for the system delivering power to the 50-ohm input of the field strength meter. For example:

Field Intensity in dBuV/m= FSM reading in dBuV + cable loss in dB +pad loss + Antenna Factor.

By providing the sum of all of the gains and losses between the field and the meter, the field intensity may be calculated and displayed on the Field Strength Meter front panel directly in dBuV/m. When a PC application is controlling/reading the meter, the PC can do the calculating and display/record true field intensity readings for the operator.

APPENDIX C
Measurement Unit Conversion Chart
0dBm = 1 milliwatt into 50 ohms
(Note: 0dBuV is referenced to 1 uvolt into 50 ohms)

mV	uV	dBuV	dBm
316.23	316,228	110	3.0
281.84	281,838	109	2.0
251.19	251,189	108	1.0
223.87	223,872	107	0.0
199.53	199,526	106	-1.0
177.83	177,828	105	-2.0
158.49	158,489	104	-3.0
141.25	141,254	103	-4.0
125.89	125,893	102	-5.0
112.20	112,202	101	-6.0
100.00	100,000	100	-7.0
89.13	89,125	99	-8.0
79.43	79,433	98	-9.0
70.79	70,795	97	-10.0
63.10	63,096	96	-11.0
56.23	56,234	95	-12.0
50.12	50,119	94	-13.0
44.67	44,668	93	-14.0
39.81	39,811	92	-15.0
35.48	35,481	91	-16.0
31.62	31,623	90	-17.0
28.18	28,184	89	-18.0
25.12	25,119	88	-19.0
22.39	22,387	87	-20.0
19.95	19,953	86	-21.0
17.78	17,783	85	-22.0
15.85	15,849	84	-23.0
14.13	14,125	83	-24.0
12.59	12,589	82	-25.0
11.22	11,220	81	-26.0
10.00	10,000	80	-27.0
8.91	8,913	79	-28.0
7.94	7,943	78	-29.0
7.08	7,079	77	-30.0
6.31	6,310	76	-31.0
5.62	5,623	75	-32.0
5.01	5,012	74	-33.0
4.47	4,467	73	-34.0
3.98	3,981	72	-35.0
3.55	3,548	71	-36.0
3.16	3,162	70	-37.0
2.82	2,818	69	-38.0
2.51	2,512	68	-39.0
2.24	2,239	67	-40.0
2.00	1,995	66	-41.0
1.78	1,778	65	-42.0
1.58	1,585	64	-43.0
1.41	1,413	63	-44.0
1.26	1,259	62	-45.0
1.12	1,122	61	-46.0
1.00	1,000	60	-47.0
0.891	891	59	-48.0
0.794	794	58	-49.0
0.708	708	57	-50.0
0.631	631	56	-51.0
0.562	562	55	-52.0
0.501	501	54	-53.0
0.447	447	53	-54.0
0.398	398	52	-55.0
0.355	355	51	-56.0
0.316	316	50	-57.0
0.282	282	49	-58.0
0.251	251	48	-59.0
0.224	224	47	-60.0
0.200	200	46	-61.0
0.178	178	45	-62.0
0.158	158	44	-63.0
0.141	141	43	-64.0
0.126	126	42	-65.0
0.112	112	41	-66.0
0.100	100	40	-67.0
0.089	89.1	39	-68.0
0.079	79.4	38	-69.0
0.071	70.8	37	-70.0
0.063	63.1	36	-71.0
0.056	56.2	35	-72.0
0.050	50.1	34	-73.0
0.045	44.7	33	-74.0
0.040	39.8	32	-75.0
0.035	35.5	31	-76.0
0.032	31.6	30	-77.0
0.028	28.2	29	-78.0
0.025	25.1	28	-79.0
0.022	22.4	27	-80.0
0.020	20.0	26	-81.0
0.018	17.8	25	-82.0
0.016	15.8	24	-83.0
0.014	14.1	23	-84.0
0.013	12.6	22	-85.0
0.011	11.2	21	-86.0
0.010	10.0	20	-87.0
0.009	8.91	19	-88.0
0.008	7.94	18	-89.0
0.007	7.08	17	-90.0
0.006	6.31	16	-91.0
0.006	5.62	15	-92.0
0.005	5.01	14	-93.0
0.004	4.47	13	-94.0
0.004	3.98	12	-95.0
0.004	3.55	11	-96.0
0.003	3.16	10	-97.0
0.003	2.82	9	-98.0
0.003	2.51	8	-99.0
0.002	2.24	7	-100.0
0.002	2.00	6	-101.0
0.002	1.78	5	-102.0
0.002	1.58	4	-103.0
0.001	1.41	3	-104.0
0.001	1.26	2	-105.0
0.001	1.12	1	-106.0
0.001	1.00	0	-107.0
0.001	0.89	-1	-108.0
0.001	0.79	-2	-109.0
0.001	0.71	-3	-110.0
0.001	0.63	-4	-111.0
0.001	0.56	-5	-112.0
0.001	0.50	-6	-113.0
0.000	0.45	-7	-114.0
0.000	0.40	-8	-115.0
0.000	0.35	-9	-116.0
0.000	0.32	-10	-117.0