JT44: New Digital Mode for Weak Signals

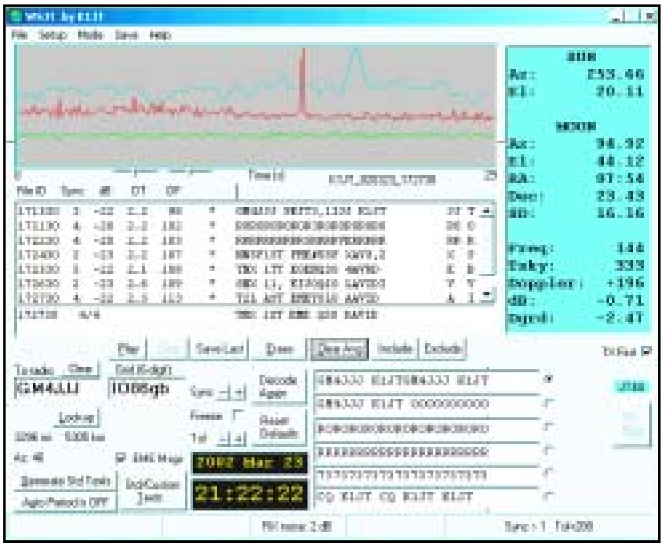
By Joe Taylor, K1JT

Version 1.0 of *WSJT* (Weak Signal Communication by K1JT) was described in detail in the December 2001 issue of *QST*. Its FSK441 mode enables one to use a personal computer running the *Windows* operating system to control an SSB transceiver (interfaced to the radio through the sound card and a serial port) to communicate digitally with other similarly equipped stations. FSK441 is especially suited for very short bursts of weak but audible signals, typical in meteor-scatter communication.

The current revision of *WSJT* (1.9.4) is a beta release that will soon become a major new program, *WSJT* Version 2.0. In addition to its highly successful FSK441 mode, the new program introduces a mode called JT44, designed for communicating with signals that are extremely weak but approximately steady in amplitude. Using this protocol at both ends of the path, JT44 can decode signals that are 10 dB or more below the weakest CW signals that can be copied by ear. This sensitivity makes the program extremely attractive for extended tropospheric scatter, ionospheric scatter and EME propagation on the amateur VHF, UHF and microwave bands.

During the first three weeks of JT44's availability, dozens of 2-meter EME QSOs have been made with it. In addition, numerous terrestrial contacts have been made on bands from 50 MHz to 10 GHz in the 600 to 1200-km range, often using QRP power levels. One of the early EME QSOs was my own first-ever contact off the Moon on March 23 with GM4JJJ on 144 MHz. It was quite a thrill for me and surprisingly easy. Fewer than ten minutes elapsed from moon rise in New Jersey to reception of final RRRRs by both stations. Although I am hardly QRP, my station is not what is generally considered to be in the EME-class: about 400 W to four nine-element Yagis, without elevation control.

The new signaling mode is called JT44 because it encodes messages using 44 distinct tones. Both computer clocks must be set to within about ±1 second of the correct time. Much more precise synchronizing is established by the decoding computer, from the message content itself. Transmit and receive periods are computer controlled and last for 30 seconds each, starting on UTC half-minutes. Transmitted audio starts at 1.0 second into the half-minute and lasts for about 25.1 seconds. The remaining 3.9 seconds of the 30-second period provide idle time for TR switching, EME propagation delay and compensation for computer clock errors.



The main screen of *WSJT* in JT44 mode displays K1JT's EME contact with GM4JJJ. The large text box shows WSJT's attempts to decode GM4JJJ's signal in successive 30-second reception periods.

The JT44 message format involves 135 equal intervals of time, each about 0.19 seconds long, in which a single tone is transmitted. In 69 of the intervals, the tone frequency is 1270.5 Hz, used as a synchronizing frequency. The remaining 66 intervals transmit tones at any of the frequencies $(N+120)*10.7666$ Hz, where N is an integer between 1 and 43. Different values of N correspond to the digits 0 through 9, letters A through Z, and special characters ". , / # ? $" and space. The 66 character intervals convey a 22-character fixed-length message, repeated three times in each sequence.

The 69 sync-tone and 66 character-tone intervals are interleaved according to a pseudorandom sequence that has the desirable mathematical property of allowing the receiving station to synchronize in both time and frequency with the transmitting station. Detecting and aligning the sync-tone pattern is the principal secret weapon of JT44. In practice, it allows the software to accommodate frequency offsets between transmitting and receiving stations as large as ±600 Hz, and relative clock errors in the range from –2 to +4 seconds. An asymmetrical time range was chosen to enable *WSJT* to readily accommodate the extra 2.5 seconds of EME propagation delay.

This Month

June 8-10	ARRL June VHF QSO Party
June 16	Very Good EME Conditions
June 15-16	SMIRK Contest

Using slightly more than half of the transmission time for the synchronizing tone costs approximately 1.5 dB in signal-to-noise (S/N) ratio. This turns out to be an excellent trade-off in practice. It means that transmissions will synchronize reliably at the receiving end, even when the S/N ratio is around –25 dB relative to the received noise power in a 2500-Hz bandwidth. Notice that by comparison, the minimum CW signal strength that can be copied is about –11 dB relative to the same noise level. JT44 can get through with solid copy even when you cannot hear the other station's signals.

Single letters in the 22-character message will have worse S/N ratios than that of the sync tone by a factor equal to the square root of 69/3, or 6.8 dB. However, that loss can be made up by averaging the received character-tone spectra over many 30-second reception periods. For such incoherent averaging, each doubling of the number of periods buys you 1.5 dB in S/N. Four periods gets you 3 dB improvement, 16 periods gets 6 dB and so on. If the signal strength remains reasonably steady, these numbers mean that good copy of any message that can

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144 MHz Standings

Published 144 MHz standings include call-area leaders as of April 1. For a complete listing, check the Standings Boxes on the World Above 50 MHz Web pages at **www.arrl.org/qst/worldabove/**. To insure that the Standings Boxes reflect current activity, submit reports at least every two years by e-mail to **standings@arrl.org**. Printed forms are available by sending a request with SASE to Standings, ARRL, 225 Main St, Newington, CT 06111.

Call Sign	*State or Province*	*States*	*DXCC*	*Grids*	*Best DX (km)†*
K1MS *	MA	50	32	—	—
AF1T *	NH	50	28	—	2240
W1AIM *	VT	50	18	196	2276
K1UHF *	CT	45	22	232	2583
WA1JOF *	ME	43	33	154	2534
K1SIX *	NH	43	14	201	2501
W1REZ	ME	36	6	181	2587
K1TEO	CT	36	5	218	2420
W3EP/1	CT	36	3	173	2450
K1LPS	VT	31	2	96	2273
W1LP	MA	30	5	110	—
W2CNS *	NY	50	22	125	2367
N2WK *	NY	47	40	293	2298
K1NY	NY	37	4	151	2619
WB2CUT	NJ	37	2	149	—
W2MPK *	NY	36	8	—	—
K2OVS	NY	36	4	120	2812
K1JT	NJ	36	3	120	2123
WV2C	NY	33	4	138	2450
W3CMP *	PA	50	64	408	—
KI3W *	PA	50	61	337	2428
W3EME *	PA	50	26	151	—
WA2FGK *	PA	44	35	223	—
N3FA *	PA	37	17	122	2420
AE3T	PA	37	3	—	2510
W3BO	PA	35	3	121	2200
K3KEL	PA	35	2	125	2120
K3ZO	MD	34	1	120	—
WA3BZT *	DE	33	17	111	2418
WA3DMF	MD	32	4	55	2050
W8WN *	KY	50	50	327	2273
WA4MVI *	SC	50	44	—	2498
W4MW *	NC	50	36	—	—
NB2T	FL	44	2	82	2270
K4MRW	AL	41	5	252	—
K4RF	GA	40	4	212	2147
W4WTA	GA	40	4	170	2413
W4DEX	NC	40	—	—	—
W4MOS	FL	39	9	—	—
KD9KP	TN	39	3	151	2180
K4QIF *	VA	39	2	—	—
WB5APD	GA	37	6	220	2005
K4QI	NC	37	5	206	—
AA4H	TN	37	3	167	2007
N4LGY	TN	37	3	145	2821
WA4HFN	TN	37	2	157	—
KU4WW	AL	37	2	140	2968
K4ZOO	VA	36	4	190	2162
KG4BMH	TN	36	2	126	1876
K4RWP	TN	36	1	161	—
N4MM	VA	35	5	149	—
WB2QLP	FL	34	6	214	2050
W4EUH	GA	33	3	111	2175
W5LBT *	LA	50	130	325	—
W5ZN *	AR	50	36	305	2400
WD5AGO *	OK	50	33	255	2050
W5UWB *	TX	50	29	104	2197
W5RCI *	MS	50	23	272	2150
K5CM *	OK	50	—	—	—
N5KW	OK	50	—	—	—
W5LUA *	TX	50	—	—	—
K5UR	AR	48	5	461	—
K5SW	OK	47	5	291	2269
KM5ES	OK	43	4	175	2369
W5HNK	TX	37	3	—	2442
NEØP	OK	37	2	79	2171
WA5JCI	TX	36	5	188	—
NL7CO	OK	36	2	131	2151
AA5C	TX	34	2	174	2202
WA5IYX	TX	32	2	110	2243
K5TN	OK	32	1	128	2025
AA5AM	TX	31	3	124	2271
K6AAW *	CA	50	54	334	3831
WA6PEV *	CA	50	52	—	—
K6PF *	CA	34	21	—	—
K6QXY *	CA	24	8	—	3794
N6ZE *	CA	22	16	115	2600
N6YM	CA	21	4	142	3822
W6TOD	CA	21	3	—	—
W7HAH *	MT	50	90	501	—
W7RV *	AZ	50	29	257	2937
WA7KYM *	WY	49	29	233	2359
AA7A *	AZ	48	47	387	2983
N7EIJ *	ID	39	25	194	2399
K7XC *	NV	31	16	167	4056
WA7GSK	ID	29	2	193	3032
NJ7A	UT	24	3	138	2104
K8BHZ *	MI	50	45	362	2278
W8PAT *	OH	50	35	178	2207
W8WVM *	WV	50	29	135	1560
WA8WZG *	OH	46	21	196	2235
K8MD	MI	40	3	194	1362
WA8EOJ	OH	39	3	199	2198
K2YAZ	MI	38	2	162	2167
N8KOL	OH	38	2	160	2035
KB8O	MI	36	1	171	—
W8QXO	OH	36	1	—	2092
WA8LKD	MI	35	2	123	1961
NØAKC *	WI	50	30	228	2295
W9EME *	WI	44	18	—	2500
W9JN	WI	43	5	221	2261
WØUC	WI	41	2	185	2192
N9NJY	IL	38	3	105	2100
WA9PWP	WI	32	2	133	1940
KA9UZW	WI	30	2	122	1884
WØHP *	MN	50	84	—	—
KØPW *	MN	50	39	356	2362
KØFF *	MO	50	34	267	2185
WØVD *	MO	50	26	307	—
W7XU/Ø	SD	48	2	243	2180
KMØA *	MO	47	11	387	2780
NØLL	KS	47	3	377	2378
NØHJZ	MN	46	2	222	2500
WØGHZ	MN	46	2	167	2570
KWØA	MO	45	2	244	2501
WØOHU	MN	45	2	173	2040
KØCJ	MN	44	2	—	2330
WAØKBZ *	MO	43	4	170	—
WØJRP	MO	43	3	219	2340
KMØT	IA	43	2	135	2308
KØGU *	CO	42	37	278	2400
KDØPY	IA	41	2	206	2174
NØUK *	MN	41	2	182	2053
KØAWU	MN	41	2	129	2095
NØNZ	NE	39	2	153	2224
WØZQ	MN	38	2	180	2610
KAØPQW	MN	34	2	—	2122
KØVSV	IA	33	2	149	1835
WYØV	IA	33	2	119	—
NØDQS	IA	33	1	120	2048
WA2HFI/Ø	MN	31	2	126	2057
Canada					
VE1ALQ *	NB	50	68	228	—
VE3KH *	ON	50	52	300	1985
VE3AX *	ON	48	33	—	2225
VE3FKX *	ON	41	8	—	—
VE3DSS *	ON	38	3	—	2190
VE3TMG	ON	30	2	156	1918
VE9AA	NB	27	2	100	2500
VE3SXE	ON	27	2	90	—
VE4KQ	MB	23	2	80	1753
DX					
KL7X *	AK	49	36	177	—

* Includes EME contacts
– Not given
† Terrestrial (non-EME)

be reliably synchronized can be achieved in about 15-20 minutes.

The *WSJT* software package has been under continued development for about a year. The code now being tested as version 1.9.4 will probably be openly released as Version 2.0 very soon. Go to the *WSJT* home page **pulsar.princeton.edu/~joe/K1JT/** to look for details. If you want to try it out right away, first install Version 1.0 and then upgrade to version 1.9.4. The Web page provides the necessary downloading, installation and operating instructions.

ON THE BANDS

Six-meter DX activity in nearly every part of the world except North America continued at high levels. The geomagnetic field was mostly quiet to active during the month, so only weak auroras appeared after 0000 on March 1, 19 and 24, mostly limited to the northern tier of US states and adjacent Canada. No other exceptional propagation conditions were reported on any band. Two groups of avid microwavers did take advantage of locally cool, dry weather to extend their distance records on 47 through 322 GHz. Dates and times are all UTC.

Six-Meter DX

From North America

Widely scattered US stations had several opportunities to work stations in Central and South America, especially early in the month. On the first, W7KNT (MT) and others in the western half of the country logged 9Y4TL, 9Z4BM, CO8LY, KP2BH, P43JB, P43MR, TI9M, VP5VAC and WP4NIX. It was probably the best day for the TI9M expedition, which logged stations in every call area, save W5 and W6. K2RTH/4 and WA2BPE found PWØT, two of the fortunate few US stations to work the expedition on Trinidade.

US stations in several parts of the country logged PY, CX, LU and CE calls, along with VP8CSA and CP6/N6XQ, during generally brief openings. The best day to catch VP8CSA was probably March 10, when he worked stations from Florida to Ohio, Kansas, Colorado, Nevada, Arizona and California. CP6/N6XQ worked K5AM (NM), K5CM (OK) and K5SW (OK) on March 26 and found more W4s and W5s on the morning of March 31. As many as a dozen W1s also made it with CP6/N6XQ between 1630 and 1700 that day.

A few stations from southern California to Florida reported brief openings into the Pacific and Asia. ZLs worked California and Texas stations on March 10, 11 and 30, including K6LMN, N6RA and W5UWB. On March 17, ZLs were reported into Florida. N6RA and K6LMN nabbed FO3BM on the 24th. K2RTH, W3BTX, N4IS and possibly others in Florida worked Japan via long-path propagation on March 15, 29 and 30, generally between 1400 and 1600. W3BTX also worked VR2KW during this period.

African stations were rare. EH8BPX worked several US stations from Florida to Maine on March 2, but that was about it from the East Coast. NØJK made a surprise contact with V51/SP6IXF around 1740 on March 6.

Activity from Hawaii was phenomenal. KF6GYM/KH6 ran Europeans as far west as CT and EH, along with EH8, via long-path on March 2, 16-18, 23, 27 and 29. Also mentioned in European reports were KH6SX, WH6O and K6MIO/KH6. Along the way, KF6GYM/KH6 picked up YJ8UU, 3D2CM and others in the Pacific.

Europe

In addition to the long-path contacts with Hawaii, Europeans continued to enjoy openings into the Middle East and Asia. Among their March catches were 7Z1SJ, HZ1MD and J28EX; VU2LO, VU2XO and VU2ZAP; YF1OO and others in Indonesia; and XV3AA. Activity along Europe-Africa paths slowed from January and February levels, but there were still some good catches. 7P8Z (Lesotho) ran 368 Europeans as far north as GW, G and SM in fewer than six hours on March 15. F1DFR worked TT8DX on March 3, and many ZS stations were still getting into Europe and the adjacent Middle East. Europeans also reported 5N6NDP, 7Q7RM, V51LK and Z21FO, along with ZD8DB in the South Atlantic.

Caribbean and South America

In addition to working North America, stations throughout the Caribbean and parts of South America also made it to Europe, the Middle East, Japan and Southeast Asia. There were transatlantic contacts on March 14, 19, 20, 22 and 24-26, at least. On March 14, ZP6CW and several PY stations worked 4Z4DX and JY9NX, and LU6KK nabbed 5B4FL. There was also good propagation from PY and LU to EH, I and other southern Europeans that morning. YV4DDK made an exceptional contact with VU2ZAP on the morning of March 15. Two days later, he logged YF1OO and YC1MH via long path, while JAs were working FG, FM, PJ and YV calls. 9H and I worked XQ3SIX (Chile) on March 22 and CP6/N6XQ on March 25.

Expeditions

Several expeditions, all clustered just either side of the geomagnetic equator, had mixed success in March. PWØT made 1530 6-meter contacts in 81 DXCC entities, but few into North America. TI9M ran 390 QSOs with 237 in the US. HKØGU and VP6DI apparently made far fewer contacts and none with US stations.

K5AND made 603 contacts in 54 DXCC entities as XRØX (San Felix Island), March 16-25. Among the first dozen calls logged were K2RTH/4, 5B4FL, JY9NX, HZ1MD, SV3KH, OD5/OK1MU and several 9H and I stations. He worked Europe and adjacent South America nearly every day, had one great run into Japan on the 25th, but had difficulty working North America. Just 67 fortunate US operators, primarily spread across the southern states from southern California to Florida, made the grade, mostly in the afternoons.

WSJT Activity

Quite a number of operators have already proven the advantages of K1JT's new JT44 mode to make weak-signal contacts that might not have been otherwise possible. K1JT and W8WN both completed 2-meter EME contacts easily using four-Yagi stations running 400 to 1000 W, several with non-EME class stations. KØSM copied both K9KNW and WA5APD off the moon during their March 18 contact with a single 13-element Yagi. A week later, RU1AA copied KØSM's 150-W signal, but they did not complete. By late May, it is likely that pairs of single-Yagi stations will have completed EME contacts using JT44.

EME is not the only use for JT44. W7SZ and W7PUA completed a 10-GHz tropo-scatter contact over an obstructed 135-km path when there was no audible signal at all. Indeed, several operators have marveled at making JT44 contacts when they could not hear the other station by ear. This may make random contacts difficult. Until JT44 operating practices are regularized, the easiest way to get started is to make a prior schedule or announce your frequency on one of the many Web-based DX and special interest packet clusters.

Microwaves

New distance marks were set on the 47 and 75-GHz bands in California and on 241 and 322 GHz bands in Virginia during early March. WØEOM completed an FM QSO on 47.040 GHz from Mt St Helena (CM88qp) to KF6KVG on Mt Umunhum (CM97ae), 172.2 km distant, just after noon on March 1. Several minutes later, WØEOM and AD6FP both completed QSOs from Mt St Helena to KF6KVG on Mt Umunhum on 75.600 GHz. In both cases, signals were 20 dB out of the noise and about as strong as the 47 GHz signals used for aiming (after one of the 10-GHz stations failed). WØEOM and AD6FP then turned their 75-GHz antennas and worked AA6IW over a 156 km-path.

WØEOM ran 60 mW to a 2-foot Cassegrain dish and a 4 dB noise figure receiver on 47 GHz, while KF6KVG ran somewhat less power to a 2-foot prime-focus dish and a similar receiver. Equipment on 75 GHz for all four stations included 4 to 10 mW transmitters, 15 dB noise figure receivers and various dish antennas from 1.5 to 3 feet in diameter.

Brian Justin, WA1ZMS, provided some updates on his group's activities on even higher frequencies. On March 1, WA1ZMS made a 500-meter CW contact with W4WWQ on 322 GHz, a 10-fold increase over their initial contact last December. Further efforts to double that distance failed. The pair extended their distance on 241 GHz to 11.4 km on March 11, after tweaking the receivers. Equipment was the same used in previous tests (see this column for March and May).

Brian is doubtful that their current equipment is capable of longer distances, primarily because of high atmospheric absorption. Although both days were relatively cold and dry, Brian calculated that atmospheric attenuation was more than 0.6 dB/km on 241 GHz and 4.5 dB/km on 322 km.

VHF/UHF/MICROWAVE NEWS

SMIRK 6-Meter Contest

The Six-Meter International Radio Club sponsors a 6-meter contest over the 48-hour period from 0000 June 15 to 2359 June 16. Contacts among US and Canadian stations may not take place in the 50.100 to 50.150 MHz segment. Modes are voice (SSB, AM, FM) and CW only. Exchange call, grid and SMIRK number (if a member). For scoring rules and other details, see **www.smirk.org**.

1296-MHz EME Beacon

W2ETI, the SETI League moonbounce beacon, has been operating experimentally on 1296.00 MHz with 150 W output since February. It transmits with a steady CW signal toward the moon for the first minute of every five-minute interval, followed by two cycles of 5-WPM CW identification. The beacon is intended to provide a constant weak-signal source for adjusting and calibrating antennas. Send reception reports to station trustee Richard Factor, WA2IKL, at **rcf@setileague.org**. For further details, see **www.setileague.org/eme**.

International EME Conference

The 10th International EME Conference, planned for Prague, Czech Republic, over the weekend of August 16-18, promises to be a memorable event. In addition to the usual technical program, there will be special sightseeing tours and a gala dinner at a castle in Prague. For full details and updates, visit **www.emeconference2002.cz**. QST

VHF/UHF CENTURY CLUB AWARDS

Compiled by Eileen Sapko Awards Manager

The ARRL VUCC numbered certificate is awarded to amateurs who submit written confirmation for contacts with the minimum number of Maidenhead grid locators (indicated in *italics*) for each band listing. The numbers preceding call signs indicate total grid locators claimed. The numbers following the call signs indicate claimed endorsement levels. The totals shown are for credits given from February 12 to April 16, 2002.

The VUCC application form, field sheets and complete list of VHF Awards Managers can be found on the VUCC Web site at **www.arrl.org/awards/vucc**. An SASE to ARRL is required if you cannot download these forms. If you have questions relating to VUCC, send an e-mail to **vucc@arrl.org**.

50 MHz
100

1204	N4IQ
1205	K2NJ
1206	KF2TI
1207	K1EY
1208	KG9IL
1209	K4SSO
1210	N7CZ
1211	W4GP
1212	WA2MUA
1213	W7SIR
1214	W3SE
1215	K2YSY
1216	NØELA
1217	VE2WBK
1218	W8SGR
1219	VE6SO
1220	KD5HIO
1221	K4MZ
EH7CD	425
G8BQX	525
WØJRP	550
NØLL	775
WA2HFI/Ø	325
WAØFQK	200
N1RK	200
K1TOL	1000
K1SIX	875
N2WK	525
N3EW	275
K3CWH	375
W3VZ	750
N3KFV	225
N4CH	750
KE4HOA	250
N4ION	225
KF4ODI	225
W4WTA	650
W4GLV	450
KU4UC	200
W5OZI	950
WD5K	925
W5DB	400
AA5XE	650
AE5B	325
K6QG	300
N6JV	475
KB6NAN	550
N7DB	500
K7MAC	275
N7AU	200
NL7CO	200
KB8GC	225
KB8UUZ	200
K8SIX	600
W8UV	200

144 MHz
100

598	K4SSO
599	KØAWU
NL7CO	125
K7MAC	150
K8SIX	175

222 MHz
50

109	W1AIM

432 MHz
50

294	KC6ZWT
295	KØAWU
296	N4ION

902 MHz
25

33	WA8RJF

10 GHz
5

119	N1JEZ
120	N1GJ
AA5C	40

Satellite
100

114	N1HOQ
115	KBØCY
W6ZQ	300
K6CCC	175

QST