The J78 Antenna: An Eight-band Off-Center-Fed HF Dipole

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I had the privilege of identifying, securing and delivering complete HF and VHF/UHF stations to the amateurs on the Caribbean island nation of Dominica in the aftermath of Hurricane Maria. The HF rigs use Automatic Link Establishment (ALE), a standardized protocol by which radios participate in on-air networks.[1] To increase the chances for successful communication, the radios autonomously query each other for signal reports on agreed frequencies from 160m through 10m. Because I dedicate this 8-band antenna to the hams of Dominica (J7), I call it the "J78."

THE CHALLENGE

The Terminated Folded Dipole (TFD) is the traditional antenna of choice for HF-ALE stations because it presents a usable SWR to a single 50Ω coax feedline over a wide range of frequencies. The TFD is relatively expensive to build: it requires a high-power resistor to absorb all of the transmitter energy that would otherwise be reflected from the open ends of the wires and the high driving-point impedance necessitates a costlier 9:1 or 16:1 balun whose large choking reactance requirement may incur considerable losses.

The off-center fed dipole (OCFD) seemed like a good starting point to develop a cheaper alternative to the TFD. OCFDs aim to solve a problem that prevents the use of a center-fed dipole across several octaves of frequency: the driving-point impedance is difficult to match at even multiples of the antenna's half-wave resonant frequency. As shown in figure 1, the feedpoint of a half-wave dipole cut to resonance on 3.5MHz approaches an open circuit at 7MHz, 14MHz, 21MHz and 28MHz. Feeding the dipole at ½ its length, it's difficult to match at frequencies that are the half-wave resonant frequency times 1/(½) , 2/(½), 3/(½), etc.

OCFDs described in the ham literature usually feed the antenna at a point one-third of the length of the antenna.[2] The same matching difficulty faced by the center-fed dipole applies to this antenna, but the frequencies are different. Figure 2 shows high driving-point impedance at 10.5MHz (3.5MHz x 1/(⅓)) and 21MHz (3.5MHz x 2/(⅓)) for an 80m half-wave wire.[3] This antenna covers six ham bands, but "gives up" the 30m and 15m bands. A less well-known option is the 20% OCFD.[4] With a high driving-point impedance at 17.5MHz (3.5MHz x 1/(⅕)), figure 3 demonstrates that this design covers seven ham bands but can't be easily matched on 18m.

CAN WE DO BETTER?

First, we need to select a feed point whose position doesn't cause a harmonic of the half-wave resonant frequency to fall inside or too close to a ham band.[5] Second, we must maintain low SWR at the higher frequencies to avoid significant mismatch loss in the feedline.[6] Third, the SWR at the transmitter should be easily matched, either by the "autotuner" built in to many radios and some amplifiers or by a low-loss L-C circuit.

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[1] See hflink.com
[2] ARRL Antenna Book, 21st edition, p.7-8
[3] Note: the OCFD SWR reference impedance is 200Ω, which can be easily matched to 50Ω coax by a properly designed 4:1 current balun.
[4] Tom Rauch, W8JI, *Windom off center fed*, www.w8ji.com/ windom_off_center_fed.htm
[5] Attempting to avoid the problem by moving the feedpoint very close to a wire end produces unusable driving-point impedance at all frequencies.
[6] Mismatch loss increases with matched loss and matched loss increases with frequency.

Several feed point positions deliver useful results, but figure 4 indicates that the 45% feedpoint is a good solution for all three goals on 8 of the most-used HF amateur bands. The SWR values shown in Table 1 should be readily matched by embedded autotuners and commercially-available external matching networks. Moving the feedpoint slightly to one side or the other rebalances the 40m and 12m SWR levels, as does feeding the antenna in the vicinity of the 22.5% point, but the 45% feedpoint meets the second design goal by keeping SWR low with increasing frequency. Figure 5 depicts the construction details of the J78.

The *Transmission Lines for Windows* utility calculates the total power lost in a transmission line, comprising both the losses that would occur in a *matched* line and the additional losses arising from the higher voltages produced by *mismatch* conditions. Using the feedpoint impedances to determine the total feedline loss at each frequency produces the results shown in Table 1.

Table 1 Total line loss vs. frequency for J78 with 50-ft of RG8X

Operating Frequency	Feedpoint SWR	Feedpoint Impedance (Ω)	Line Loss (dB)	Mismatch Line Loss (dB)	Total Line Loss (dB)
3.6MHz	2.6	22+j17	0.19	0.01	0.20
7.1MHz	5.7	272+j63	0.26	0.52	0.78
10.1MHz	5.6	29-j71	0.31	0.55	0.86
14.15MHz	1.8	91+j3	0.36	0.08	0.44
18.1MHz	3.8	86+j86	0.40	0.30	0.70
21.25MHz	1.1	54-j1	0.44	0.00	0.44
24.9	2.8	135+j22	0.47	0.22	0.69
28.4MHz	1.2	42+j3	0.50	0.00	0.50

Given the advantages of being able to operate on eight amateur bands between 3.5MHz and 30MHz with a single wire antenna and feedline, a maximum loss in the vicinity of 1dB seems an acceptably small price to pay.

BALUN TRANSFORMER

The natural imbalance between the two legs of the OCFD requires careful design of the 4:1 balun.[7] A low-power, two-core Guanella (current) balun wound with 18ga speaker wire on 61-material toroid cores has been shown to deliver the required 4:1 impedance transformation with less than 0.2dB loss up to 30MHz.[8] The J78 uses 10 turns of speaker wire on each of two FT140-43 toroid cores to increase the choking reactance to about 2000Ω, in keeping with the rule of thumb that the choking reactance should be 10X the feedpoint impedance. This may increase losses at the high end of the frequency range, though no measurements were performed. Six turns of the RG8X feedline were wound through a third FT140-43 core at the balun input to further choke off imbalance currents that might otherwise flow on the outside of the shield.

The speaker wire transmission lines were wound and connected as shown in figure 6. The stacked balun cores are placed in a lightweight plastic box fitted with an SO239 connector and affixed to a fiberglass center insulator with cable ties, per figure 7.

Operating any single-wire antenna across several octaves of frequency causes substantial pattern changes from the expected single-lobed broadside pattern seen on the 80m half-wave frequency.[9] On 40m, there is several dB more gain in the direction of the longer leg of the antenna, while on 30m the broadside lobes are focused and favored by several dB over the end-fire lobes. These lobes undergo successive decomposition from 20m and up.

GET OUT THE SHOEHORN

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[7] Tom Rauch, W8JI, *4:1 balun design and operation,* www.w8ji.com/balun_single_core_41_analysis.htm

[8] John Oppenheimer, KN5L, *Speaker Wire Balun Test*, www.kn5l.net/swbalun/

[9] ARRL Antenna Book, 21st edition, p.2-11

An antenna's resonant frequency depends on its height above ground, measured in wavelengths.[10] Since a typical installation height of 50-ft is less than 0.2λ at 3.5MHz and over 1.4λ at 28MHz, the feedpoint impedance will be most affected on 80m and less affected with increasing frequency. Adjusting the overall length of the J78 to achieve resonance on 20m, while maintaining the 11:9 ratio of leg lengths that produces the 45% feedpoint position, may result in resonance below 3.5MHz as shown in figure 8. Aside from the 80m value, the frequencies of lowest measured SWR agree remarkably well with the simulated results in figure 4.

The ends of the J78 can be bent toward the ground to reduce the end-to-end span of the antenna by at least 30% without adversely affecting the SWR behavior, taking care again to change each end in the same 11:9 proportion. (Note: this reduced span is about the same as a 3-30MHz TFD.) This modification smooths out the pattern peaks and nulls from 30m and up, which may be desirable. There is also little change in the SWR when erecting the J78 as an inverted "V" or as a sloper and the pattern changes are less dramatic.

ON THE AIR

The J78 has been a welcome addition to my home station, where I haven't had a resonant WARC band antenna for over a decade. On bands where it's needed, the autotuner in my Elecraft K3-100 handles matching with ease and the antenna performed well in the 2018 ARRL Field Day. Gordon, J73GAR, has gotten good results from a J78 for the past few months. I look forward to assisting the hams of Dominica in applying this new antenna to their ALE installations.

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[10] ARRL Antenna Book, 21st edition, p.3-2

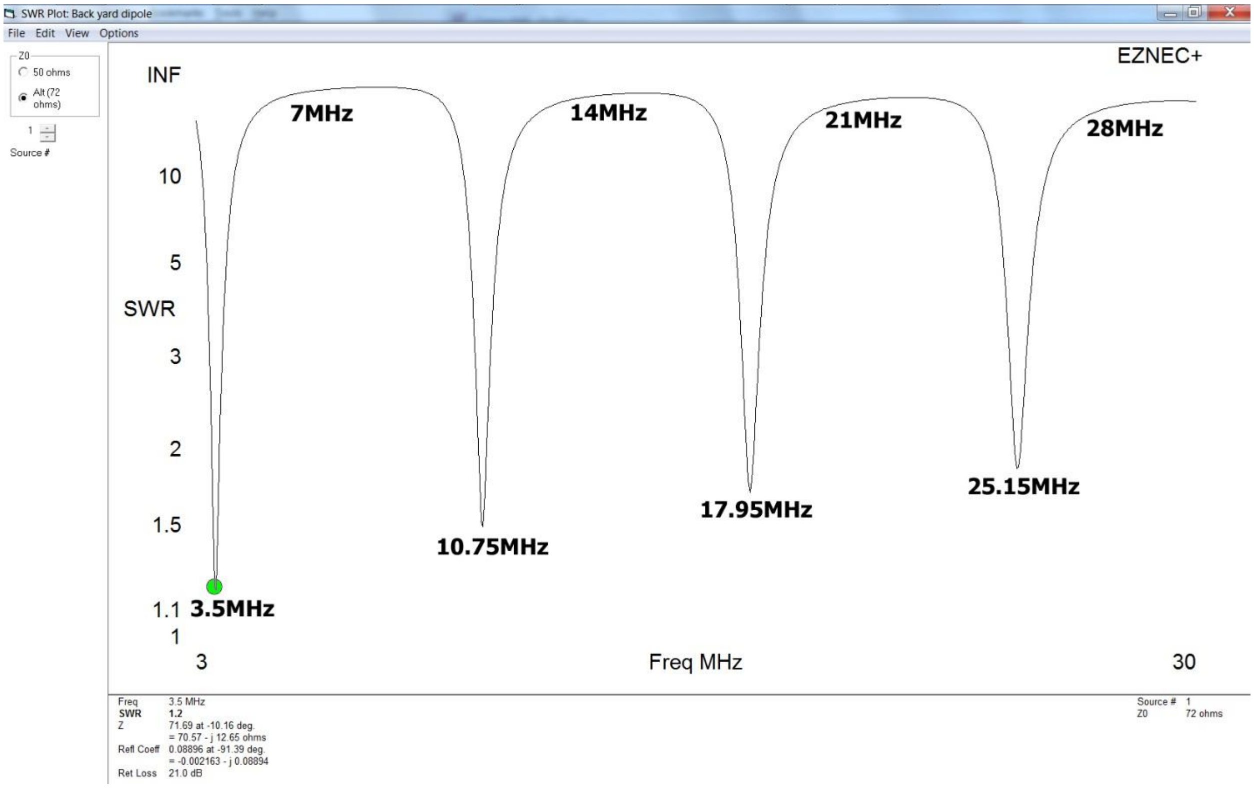

Figure 1 Simulated 72-ohm SWR plot of center-fed 80m half-wave dipole

Figure 2 Simulated 200-ohm SWR plot of 1/3-fed 80m half-wave dipole

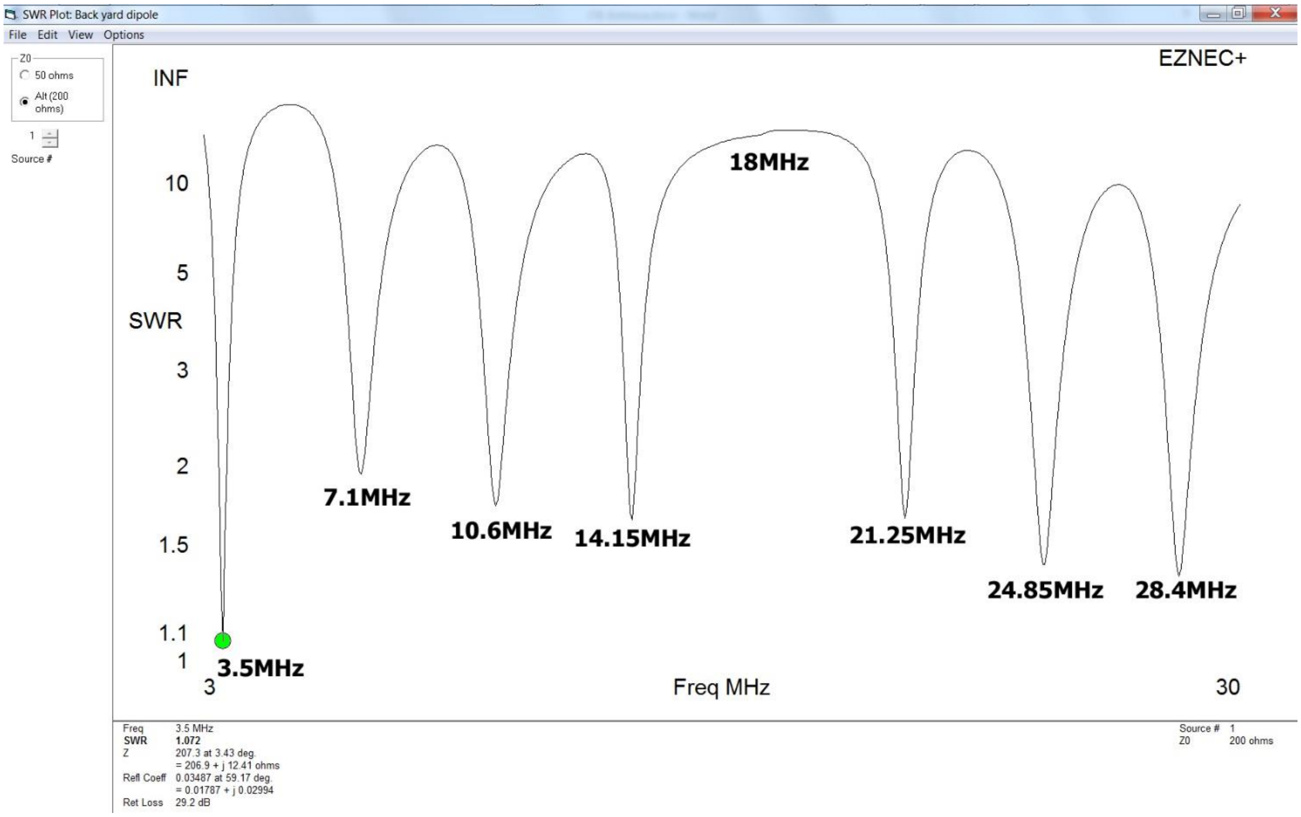

Figure 3 Simulated 200-ohm SWR plot of 20%-fed 80m half-wave dipole

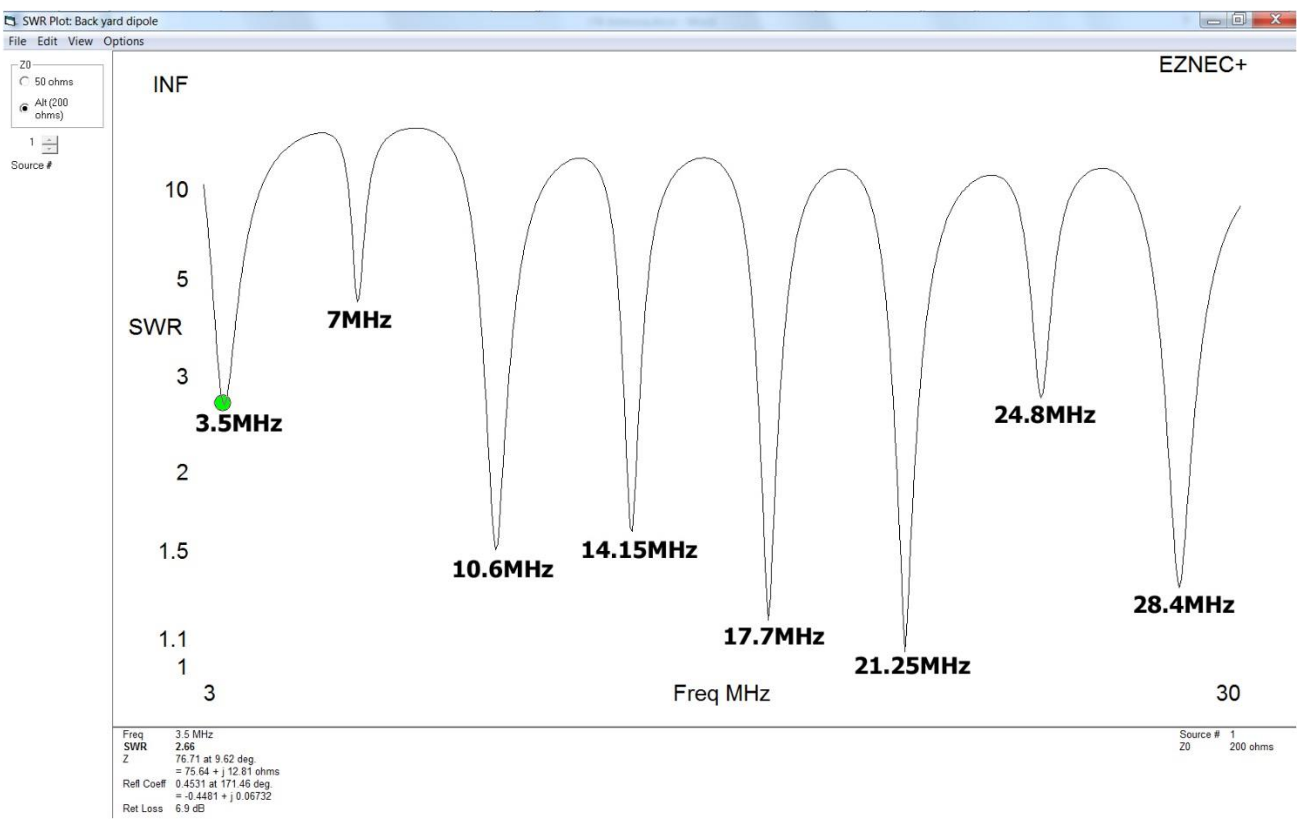

Figure 4 Simulated 200-ohm SWR plot of 45%-fed 80m half-wave dipole

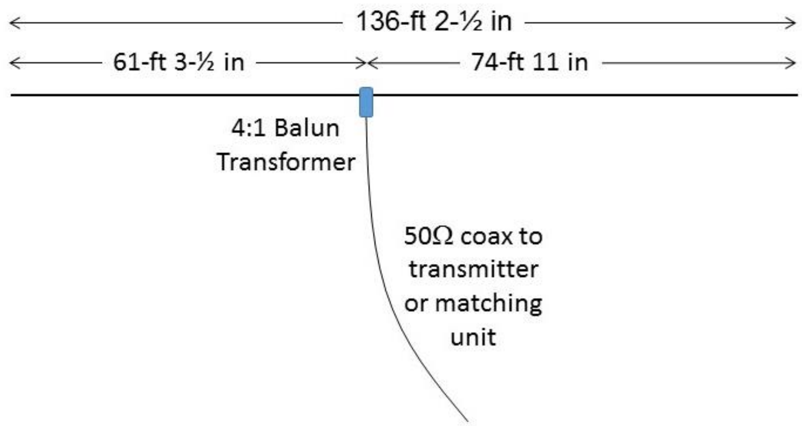

Figure 5 J78 antenna construction details

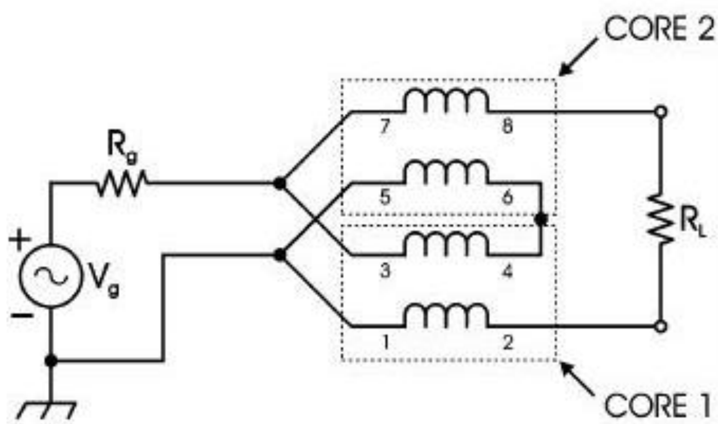

Figure 6 Winding pattern for Guanella 1:4 current balun

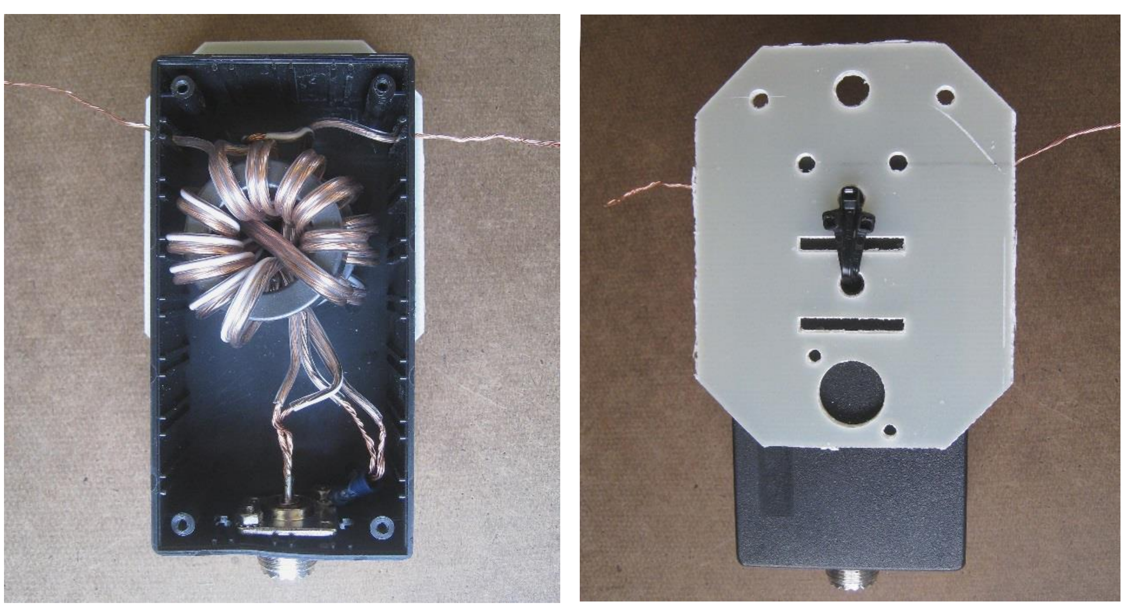

Figure 7 Front and back views of balun box and center insulator. Note "crossover" windings to place input and output connections on opposite sides of the cores.

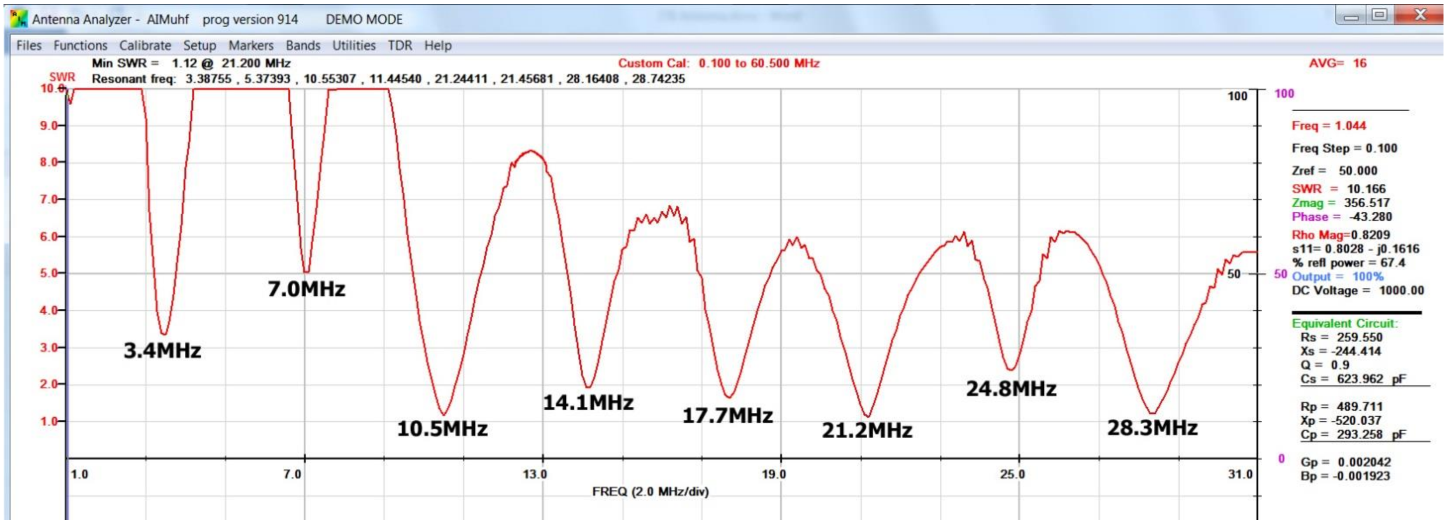

Figure 8 Feedpoint SWR of J78 at 30 feet